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CALIFORNIA FISH AND GAME

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THE FISH POPULATIONS OF SALT SPRINGS VALLEY RESERVOIR, CALAVERAS COUNTY, CALIFORNIA[1]

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[1] Submitted for publication June, 1952.

INTRODUCTION

The purpose of this study was to estimate the numbers of fish in Salt Springs Valley Reservoir, Calaveras County, by the mark-and-recapture method, primarily to appraise the possibilities of this procedure for a large warm-water reservoir. A subsidiary purpose was to obtain information for use in managing this reservoir and similar impoundments. The field work was done during the hot months of August and September, 1951, when angling pressure was almost negligible, obviating elaborate corrections for fishing mortality.

Warm-water impoundments in the Central Valley of California might be expected to yield large numbers of game fish. Yet Calhoun (1950) has presented data which indicate that the Central Valley with its many impoundments contributes rather small catches of warm-water fish compared with the Sacramento-San Joaquin Delta or the San Diego region. While it is true the impounded waters of the Central Valley lie near the heavily fished Sierra and delta areas, which are presently preferred by many fishermen, there is little doubt that they would be much more popular if they provided better fishing. Learning why they are so unproductive is the first step toward discovering how to improve them.

The problem is largely one of population size. Are the reservoirs productive? Do they have large fish populations? Is there competition between desirable and trash species? Is there a sufficient forage population to support desirable predatory species? A knowledge of the numbers of the various fish present will obviously go a long way toward providing answers to questions like these.

The determination of fish population estimates is by no means a simple task. However, several well established methods are available. Of these, the mark-and-recapture technique presently seems to offer the greatest possibilities (Kennedy, 1949). Its earliest use is usually credited to Petersen (1896) [*fide* Ricker (1948)]. Recent modifications and refinements have been made by Schnabel (1938) and by Schumacher and Eschmeyer (1943). Discussions of the applications and statistical interpretations have been given by DeLury (1951), Schaefer (1951a and 1951b), Fredin (1950), and Ricker (1948), among others.

ACKNOWLEDGMENTS

This investigation was carried on in cooperation with the California Department of Fish and Game, which provided the staff, equipment, and operating expenses.

It is a pleasure to express thanks to the many individuals whose aid and encouragement made this project possible. Particular thanks are given to Dr. Alex Calhoun of the Department of Fish and Game for his assistance in matters of personnel and equipment. Student biologists Richard Haley and David E. Pelgen, who helped with the field work, merit commendations for their efforts as does student biologist William E. Rowley, who assisted with compilations and computations. Thanks are due Miss Cliffa Corson for drawing the map and lettering the figures. Great appreciation is accorded Mr. Frank Tower, on whose property the base of field operations was established.

DESCRIPTION AND HISTORY OF SALT SPRINGS VALLEY RESERVOIR

Salt Springs Valley Reservoir (Figure 1) is located in Calaveras County, California. The 2,150-foot earth fill dam impounds a maximum of 10,900 acre-feet of water originating from about 21 square miles of watershed comprising the upper Rock Creek drainage basin. The reservoir is relatively shallow and the bottom slopes gently to a maximum depth of 42 feet at the dam. The maximum area at spillway level is 900 acres. At a typical annual drawdown of 12 feet the area is reduced to 412 acres, and the volume to about 3,200 acre-feet.

Salt Springs Valley Reservoir was among the first reservoirs constructed in California. The original dam, built in the 1860's, impounded about 400 surface acres of water, which was used for placer gold mining operations in the Jenny Lind and Milton areas. The heavy demand for additional water led to the building of the present dam in 1882. Subsequently gold mining operations dwindled, and the impounded water has since been used for irrigation and stock watering.

Little is known of the fish species which were stocked originally. Incomplete records made around 1900 indicate that largemouth black bass (*Micropterus salmoides*), smallmouth black bass (*Micropterus dolomieu*), bluegill (*Lepomis machrochirus*), black crappie (*Pomoxis nigromaculatus*), brown bullhead (*Ameiurus nebulosus*), white catfish (*Ictalurus catus*), and carp (*Cyprinus carpio*) had been introduced. Formerly the reservoir was used as a natural rearing area from which fish were removed for stocking elsewhere. It provided excellent bass sport fishing until about 1940, when the bass fishery declined seriously. Simultaneously, the carp and stunted black crappie populations increased tremendously.

In October, 1947, the reservoir was drawn down and treated heavily with rotenone to destroy fish populations. It was later restocked, between December, 1947, and March, 1948, with 635 adult largemouth bass and 1,150 adult bluegills, amounting to approximately one bluegill per surface acre and one bass per two surface acres.

In the summer of 1949, only a year and a half later, a few anglers reported excellent catches of small bass. Some limit catches of 25 good-sized bluegills were reported later that summer. It may be assumed that many of the age I+ fish rather than the brood stock were supporting the fishery in 1949.

A sampling of the juvenile fishes by rotenone treatment of a small bay during autumn, 1950, indicated a pronounced lack of suitable forage species for the abundant small bass. Consequently, 2,000 four- to six-inch golden shiners (*Notemigonus crysoleucas*) were introduced during October, 1950, with the hope of improving the forage situation.

The 1951 spring and early summer season was quite successful for the bass fishermen and many limit catches of five bass were made. It is roughly estimated that as many as 5,000 to 8,000 bass were removed during this season. The bass caught by anglers were generally small, perhaps averaging between 10 and 11 inches in length. While some good catches of bluegills were made, the total 1951 catch seemed to be quite small. From time to time an occasional brown bullhead, white catfish, or carp appeared in the catches.

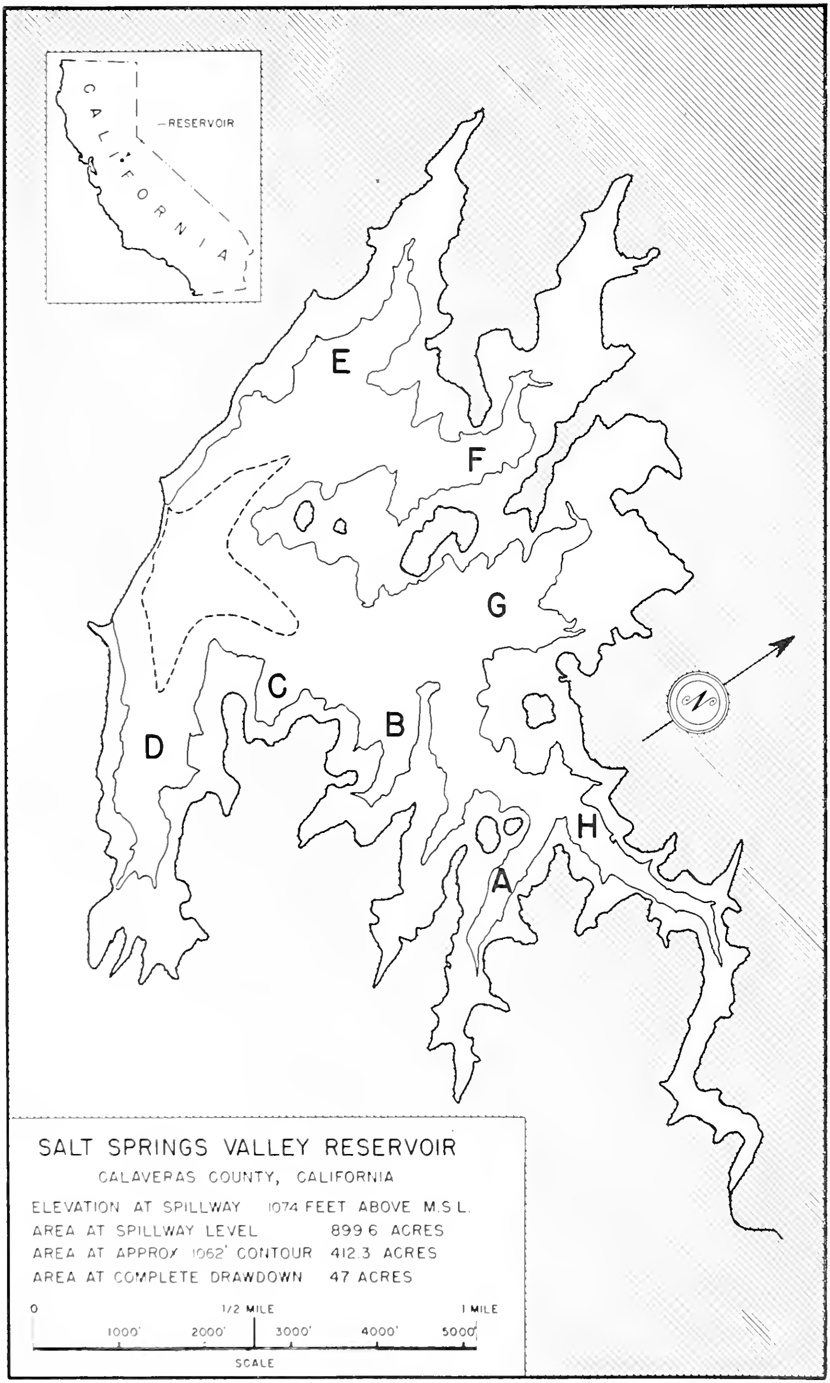

FIGURE 1. Map of Salt Springs Valley Reservoir, Calaveras County, California

Earlier in the 1951 season, the fish appeared to be relatively free of "worms," "grubs," and other parasites. By late summer and early autumn, however, most of the bass and bluegills were heavily parasitized by a roundworm, identified as a larval stage of *Contracaecum spiculigerum* by Mr. Harold Wolf, Bureau of Fish Conservation parasitologist. Casual field observations revealed that even heavily parasitized fish were in good condition.

Little is known of the other biota in Salt Springs Valley Reservoir. Though emergent shoreline vegetation is generally lacking, the reservoir contains fair quantities of a pondweed (*Potamogeton* sp.), locally abundant filamentous algae, and prodigious quantities of a colonial bryozoan, *Pectinatella*, whose "jelly-balls" with diameters up to three feet clog many of the shallower bays. Several small bluegills, whose stomach contents were examined, were gorged with bryozoan statoblasts. Extremely dense swarms of Tendipedidae (=Chironomidae) midges during August and September, 1951, gave indirect indication of a fairly good bottom fauna at this time of the year. Otherwise there is no information on the kinds and amount of either benthos or plankton.

The limnology of the reservoir has not been studied. Evidence of a temporary lack of oxygen in deeper waters was found during a prolonged calm, hot period in mid-August. At this time fish of all species caught in traps below depths of 14 to 16 feet were dead. With the appearance of winds several days later, this condition disappeared.

METHODS

In this study the sizes of the fish populations were estimated by the well known mark-and-recapture technique described by Schnabel (1938). Accounts of the application of this method have been given by Ricker (1948), Schaefer (1951a, 1951b), and DeLury (1951). Essentially, the technique involves capturing successive random samples of fish; marking and releasing those in each sample; and noting the number of recaptures in each sample after the first.[2]

In this study, estimates were made of the numbers of largemouth black bass, bluegill, carp, brown bullhead, and white catfish present in the lake between August 7 and September 19, 1951, using successive samples of trapped and seined fish.

[2] If each of t successive samplings is carried out over a short period of time, say for one to seven days, then

B_t = the total number of fish marked and at large just before the tth sample,
A_t = the number of fish sampled at the tth interval, and
C_t = the number of recaptured fish among those of the tth sample.

If there is no difference between the marked and unmarked fish, if all sampling and distribution of marked fish is random, and if the population remains unchanged during the mark-and-recapture operations, the following relationship holds where P is the size of the total population:

$$\frac{C_t - A_t B_t/P}{1 - B_t/P} = 0.$$

Since the equation in this form can be solved only approximately for P, and since the denominator nearly equals unity when the total number of marked fish at large is small in relation to the total population, an estimate of P,

$\hat{P}$, may be given as $\hat{P} = \dfrac{\Sigma(A_t B_t)}{\Sigma(C_t)}$

If a given number of marked fish, B, is released and sampling is continued

$$\hat{P} = \frac{(B)\Sigma(A_t)}{\Sigma(C_t)}$$

Traps were constructed of one-inch mesh poultry wire, as described by Wohlschlag (1952). The seine was 200 feet long, 15 feet deep in the middle, and tapered to six feet at the ends; it was made of No. 6 medium twine with a stretched mesh measure of 1.5 inches; it was fitted with 2.5-inch corks and number 12 leads spaced at two-foot intervals.

The seining procedure was to pay the net out from a platform on the bow of a 14-foot boat which was being pulled along backwards by a reversible five-horsepower motor. In this way a large semicircle was formed with the ends of the seine in about three feet of water. It was hauled and beached by two men, while a third man remained near the center to clear snags and prevent rolling.

Each individual sample covered the whole reservoir. To insure good distribution of sampling and release of marked fish, the reservoir was divided into eight areas, designated A to H in Figure 1. Two were ordinarily seined and trapped each day. Under this schedule each sampling took four days. The sampling in each area consisted of two seine hauls and 10 trap sets. Traps were emptied in the morning and evening each day. Within each area four traps were set at a depth of about 10 feet, four at about 15 feet, and two at about 20 feet.

Trapping and seining were usually simultaneous for each sampling period, although at times there was a disparity of a day or two. The schedule of sampling periods is given in Table 1.

Fish were removed immediately after capture to a tub or floating live car. Only the fork lengths to the nearest millimeter were recorded for each fish handled, because the heat made rapid handling necessary. Scale samples and weight records were obtained for small, selected samples.

TABLE 1

Schedule of Seining and Trapping Operations in Salt Springs Valley Reservoir During August and September, 1951

Period	Seining operations			Trapping operations		
	Dates	Days elapsed from period 1[1]	Days between periods	Dates	Days elapsed from period 1[2]	Days between periods
1.	7-10 Aug.	0		7-11 Aug.	0	
			6			5
2	13-16 Aug.	6		12-16 Aug.	5	
			4.5			4
3	17-21 Aug.	10.5		16-20 Aug.	9	
			4.5			4
4.	22-25 Aug.	15		20-24 Aug.	13	
			5			6
5	27-30 Aug.	20		26-30 Aug.	19	
			7			7
6	3-6 Sept.	27		2-6 Sept.	26	
			4.5			4
7.	7-11 Sept.	31.5		6-10 Sept.	30	
			4			
8.	12-14 Sept	35.5				
			5			
9	17-19 Sept.	40.5				

[1] Calculated from middle of 7-10 August period.
[2] Calculated from middle of 7-11 August period.

Largemouth black bass, brown bullheads, white catfish, and golden shiners were marked during all but the last periods of seining and trapping. Bluegill marking was discontinued after the third period of seining and after the fourth period of trapping. All carp marking was discontinued after the third period. Seined fish were marked by removing the left ventral (LV) fin; trapped fish were marked by removing the right ventral (RV) fin. All fish, whether marked or not, were released near the location of their capture, except that all seined and trapped carp were removed from the lake and destroyed after the third period.

RESULTS AND CALCULATIONS

Population of Largemouth Bass

Because only 68 bass were taken in traps, they have been included with those which were seined.

The capture-recapture data with Schnabel-type population estimates are given in Table 2. The final estimate uncorrected for recruitment (except for the partial correction implied by raising the minimum size limits of the fish handled) is

$$\hat{P} = \frac{\Sigma(A.B)}{\Sigma(C)} = \frac{2{,}047{,}596}{105} = 19{,}501.$$

Confidence limits at the 0.95 level, calculated for the quantity (C) by using Chapman's Table II and formula (46) (Chapman, 1948), are 15,881 to 23,347.

TABLE 2

Data for Estimation of Largemouth Bass Population of Salt Springs Valley Reservoir During August and September, 1951, on Basis of Combined Seine and Trap Catches

Period	Days elapsed[1]	Minimum size handled (mm.)	Total number handled (A)	Total number marked and released	Total number marked large (B)	Number of recaptures (C)
1	0	95	127	127	0	0
2	6	95	113	112	127	1
3	10.5	95	199	185	239	7
4	15	100	321	311	424	10
5	20	105	257	247	735	8
6	27	105	330	310	982	15
7	31.5	105	435	399	1,292	31
8	35.5	105	242	222	1,691	13
9	40.5	105	191	0	1,913	20

[1] Computed from middle of 7-10 August period for seined fish.

Fork length frequency distributions in five millimeter groupings for seined bass only are illustrated in Figure 2. Small young-of-the-year and yearling bass were observed to be feeding actively on small bluegills, and their growth rate was rapid. The breaks marked with arrows in the length frequency histograms in Figure 2 are believed to represent roughly the same group of fish in successive samples. The midpoints of the corresponding intervals have been plotted against the mid-dates of the seining Periods 3 to 9 in Figure 3. Growth was nearly linear, and

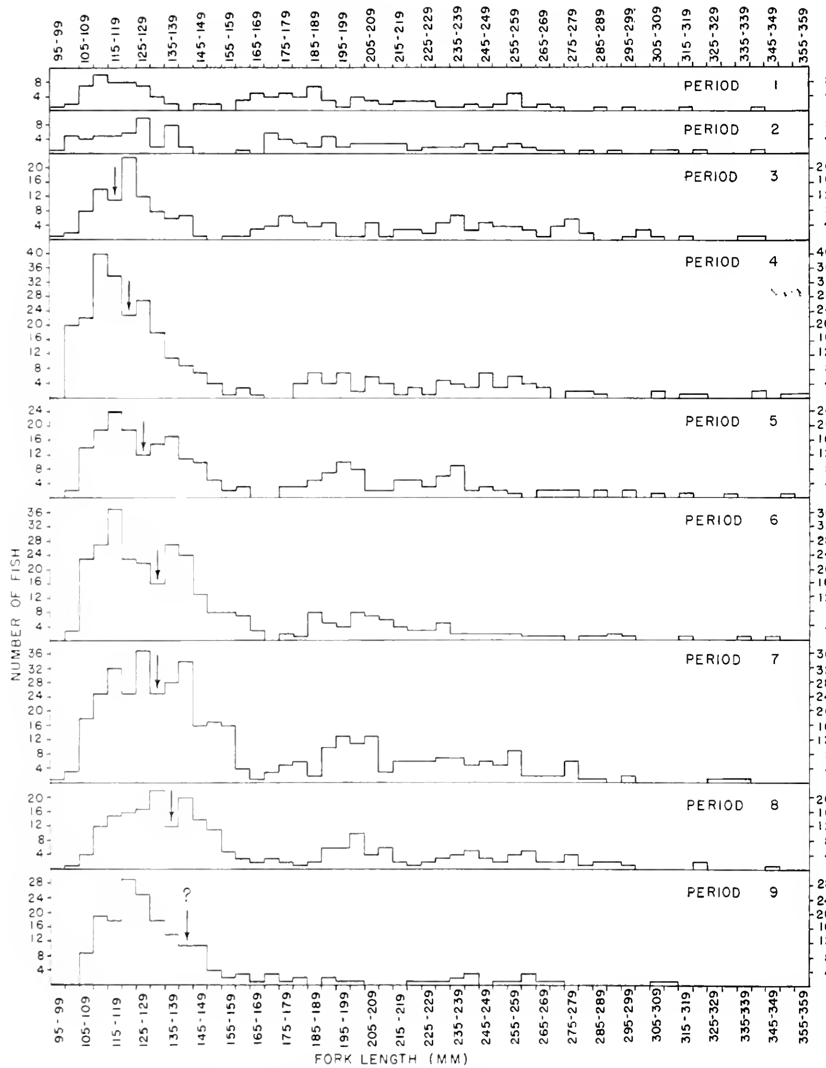

FIGURE 2. Length frequency histograms of largemouth bass seined during nine periods of sampling in Salt Springs Valley Reservoir during August and September, 1951

TABLE 3

Data for Estimation of the Salt Springs Valley Reservoir Bass Population From Combined Trap and Seine Catches Corrected for Recruitment

Period	Minimum size handled (mm.)	Total number handled (A)	Total number marked and released	Total number marked at large (B)	Number of recaptures (C)
1	97	127	127	0	0
2	102	111	110	127	1
3	107	193	181	237	7
4	109	281	274	418	10
5	112	238	229	692	8
6	118	258	242	921	14
7	121	348	316	1,163	30
8	124	201	185	1,479	12
9	128	108	0	1,664	16

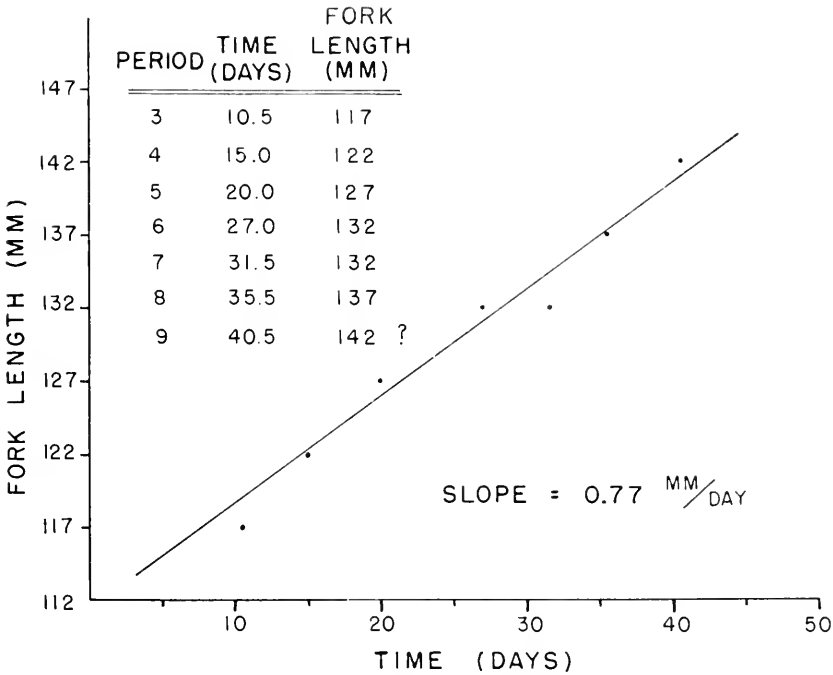

FIGURE 3. Data and diagram indicating progressive increase in lengths represented by a break in length frequency histograms (Figure 2) for largemouth bass

a least squares calculation of the slope of the line indicated a daily increase of 0.77 millimeters. At this rate, bass hatched by June could easily reach five to six inches by autumn. Young-of-the-year bass of this size were quite numerous by autumn in Salt Springs Valley Reservoir.

One result of this rapid growth was a progressive increase in the numbers of small fish retained by the seine. This recruitment will tend to bias the population estimate upward as discussed in detail in a later section. The black bass estimate was corrected for recruitment by starting

with a minimum size of 95-99 millimeters (midlength of 97 millimeters) for Period 1, gradually increasing to 128 millimeters in Period 9. The revised data are shown in Table 3. The corrected population estimate is

$$\hat{P} = \frac{\Sigma(A.B)}{\Sigma(C)} = \frac{1,462,579}{98} = 14,924.$$

The 0.95 confidence limits are 12,139 to 18,282. The difference between the two estimates is too small to be of much concern, in view of the limitations of the field procedures on which they are based.

Weight of the Bass Population

The fork length-weight relationships for a selected sample of 186 largemouth bass taken in August and September are shown in Figure 4. When these data are plotted as logarithms of the weights (W) in grams

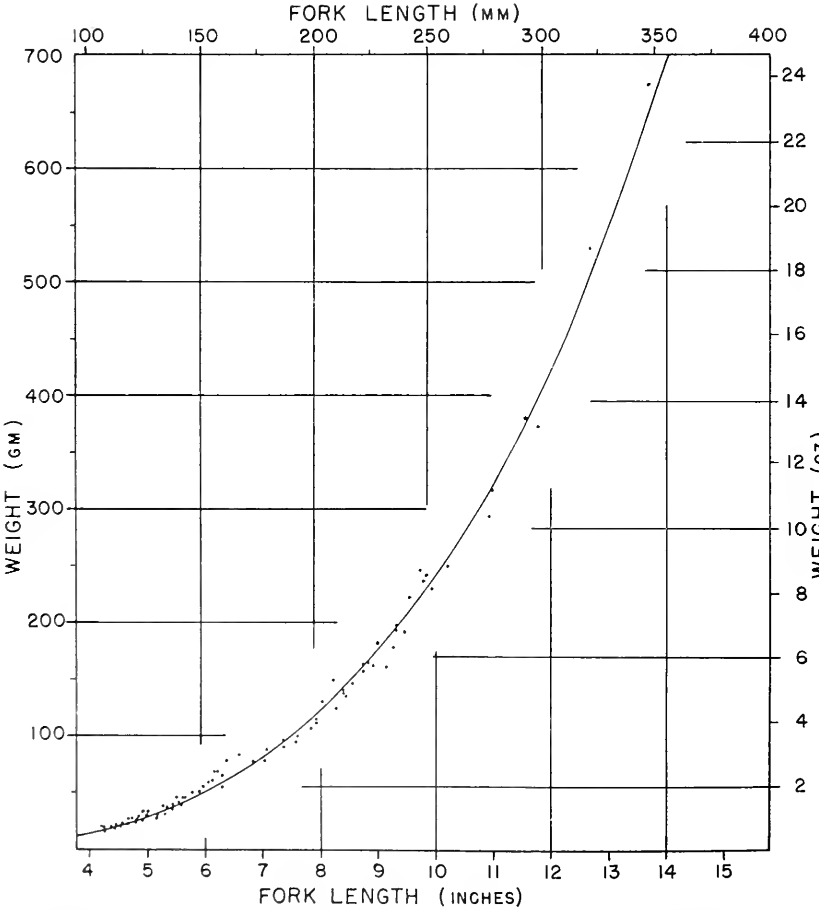

FIGURE 4. Length-weight relationships for largemouth bass taken in Salt Springs Valley Reservoir during August and September, 1951. Linear relationship is log weight in grams $= -5.00462 + 3.07612$ log fork length in millimeters.

against the logarithms of the fork lengths (L) in millimeters they show reasonable linearity, and the straight line equation derived by the method of least squares describes the relationship

$$\log W = -5.00462 + 3.07612 \log L.$$

The bass population was considered to be adequately represented by the combined length frequency distribution of Periods 1 and 2. For each five-millimeter length group, the midclass lengths, the percentage frequencies, the numerical frequencies, the calculated average weights per fish, and the gross weights of the length group were calculated and tabulated (Table 4) for both the uncorrected and the recruitment corrected estimates. The relative crudeness of these calculations must be emphasized.

The totals in Table 4 also include the weight of bass whose fork lengths were 230 millimeters (nine inches) or longer. Fish of the larger size group are, of course, of greatest interest to anglers; they comprise only one-fifth of the estimated population numbers and over half of the total estimated weight within the size-range sampled.

Population Estimates of Seined Bluegills

The numbers of both seined and trapped bluegills which were sampled, marked, and recaptured are given in Table 5. The length-frequency diagrams for each of the periods are given separately for seined and trapped fish in Figure 5.

From data in the first part of Table 5 for seined fish, it was impossible to calculate a sensible Schnabel estimate of the bluegill population by utilizing the simultaneous mark-and-recapture records for the first four periods. The four-period estimate,

$$\hat{P} = \frac{\Sigma(A.B)}{(C)} = \frac{5,299,908}{51} = 103,920,$$

is ridiculously low, because there were too many LV recaptures in the first several periods, when restricted seining within the eight major areas (Figure 1) was practiced. Later, however, seining was much more randomized, and the sampling data from Periods 5 to 9 can be considered much less biased. During these later periods, when marking was discontinued, the LV marked fish had also had a chance to become more widely distributed. By considering 2,646 LV marked bluegills at large during Periods 5-9, the Schnabel estimate uncorrected for recruitment or mortality would be

$$\hat{P} = \frac{(B)\Sigma(A)}{\Sigma(C)} = \frac{(2,646)\ (4,340)}{20} = 574,182.$$

The 0.95 confidence limits calculated from Chapman's (1948) Table I are 344,969 to 887,685.

TABLE 4

Breakdowns of the Uncorrected Population Estimate of 19,501 and the Estimate of 14,924 Corrected for Recruitment Into Numerical Frequencies and Calculated Weights of Seined and Trapped Largemouth Bass Within Five Millimeter Length Groups

Length class range	Midclass length		Calculated average weight per fish		Percentage of length class[1]	Population estimate of 19,501 uncorrected for recruitment and mortality			Population estimate of 14,924 corrected for recruitment only		
						Numerical frequency	Gross weight		Numerical frequency	Gross weight	
	(mm.)	(in.)	Grams	Pounds			(kg.)	(lbs.)		(kg.)	(lbs.)
95- 99	97	3.82	12.79	0.02820	0.833	162	2.1	4.6	124	1.6	3.5
100-104	102	4.02	14.93	0.03291	2.917	569	8.5	18.7	435	6.5	14.3
105-109	107	4.21	17.30	0.03814	4.583	894	15.5	34.1	684	11.8	26.1
110-114	112	4.41	19.91	0.04389	6.250	1,219	24.3	53.5	933	18.6	40.9
115-119	117	4.61	22.77	0.05020	5.417	1,056	24.1	53.0	808	18.4	40.6
120-124	122	4.80	25.90	0.05710	5.833	1,137	29.5	65.0	870	22.5	49.7
125-129	127	5.00	29.30	0.06159	7.083	1,381	40.5	89.2	1,057	31.0	68.3
130-134	132	5.20	33.00	0.07275	2.500	487	16.1	35.5	373	12.3	27.1
135-139	137	5.39	37.00	0.08157	4.167	843	30.1	66.3	622	23.0	50.7
140-144	142	5.59	41.31	0.09107	0.833	162	6.7	14.8	124	5.1	11.3
145-149	147	5.79	45.95	0.1013	0.833	162	7.5	16.5	124	5.7	12.6
150-154	152	5.98	50.93	0.1123	0.833	162	8.3	18.2	124	6.3	14.0
160-164	162	6.38	61.96	0.1366	1.667	325	20.1	44.4	249	15.4	34.0
165-169	167	6.57	68.03	0.1500	2.917	569	38.7	85.3	435	29.6	65.3
170-174	172	6.77	74.50	0.1642	4.167	813	60.5	133.5	622	46.3	102.1
175-179	177	6.97	81.36	0.1794	4.583	894	72.7	160.3	684	55.6	122.7
180-184	182	7.17	88.64	0.1954	2.947	569	50.4	111.2	435	38.6	85.1
185-189	187	7.36	96.35	0.2124	3.750	731	70.5	155.3	560	53.9	118.9
190-194	192	7.56	104.49	0.2304	3.333	650	67.9	149.7	497	52.0	114.6
195-199	197	7.76	113.10	0.2493	1.250	244	27.6	60.8	187	21.1	46.5
200-204	202	7.96	122.15	0.2693	2.917	569	69.5	153.2	435	53.2	117.2
205-209	207	8.15	131.70	0.2903	2.500	487	64.2	141.6	373	49.1	108.3
210-214	212	8.35	141.74	0.3125	2.083	406	57.6	126.9	311	44.1	97.1
215-219	217	8.54	152.27	0.3357	2.500	487	74.2	163.7	373	56.8	125.2
220-224	222	8.74	163.32	0.3601	1.667	325	53.1	117.0	249	40.6	89.6

225-229	227	8.94	174.91	0.3856	2.083	406	71.1	156.6	311	54.4	119.9
230-234	232	9.13	187.03	0.4123	1.250	244	45.6	100.5	187	34.9	76.9
235-239	237	9.33	199.71	0.4403	1.250	244	48.7	107.3	187	37.3	82.1
240-244	242	9.53	212.96	0.4695	2.083	406	86.5	190.7	311	66.2	146.0
245-249	247	9.72	226.78	0.5000	1.667	325	73.7	162.5	249	56.4	124.4
250-254	252	9.92	241.19	0.5317	1.667	325	78.4	172.9	249	60.0	132.3
255-259	257	10.12	256.22	0.5649	3.333	650	166.5	367.1	497	127.4	281.0
260-264	262	10.31	271.87	0.5994	1.250	244	66.3	146.1	187	50.7	111.8
265-269	267	10.51	288.15	0.6353	1.250	244	70.2	154.8	187	53.8	118.5
270-274	272	10.71	305.08	0.6726	0.833	162	19.6	109.3	124	37.9	83.6
280-284	282	11.10	340.91	0.7516	0.417	81	27.7	61.1	62	21.2	46.8
285-289	287	11.30	359.84	0.7933	0.417	81	29.3	64.5	62	22.4	49.4
290-294	292	11.50	379.47	0.8366	0.417	81	20.9	68.0	62	23.6	52.1
295-299	297	11.69	399.85	0.8815	0.417	81	32.5	71.7	62	24.9	54.9
305-309	307	12.09	442.71	0.9760	0.417	81	36.0	79.4	62	27.6	60.7
310-314	312	12.28	465.24	1.0257	0.417	81	37.8	83.4	62	29.0	63.8
315-319	317	12.48	488.59	1.0771	0.417	81	39.7	87.6	62	30.4	67.0
320-324	322	12.68	512.70	1.1303	0.417	81	41.7	91.9	62	31.9	70.3
340-344	342	13.46	617.10	1.3605	0.833	162	100.2	221.0	124	76.7	169.1
350-354	352	13.86	674.28	1.4865	0.417	81	54.8	120.9	62	42.0	92.5
440-444	442	17.40	1358.30	2.9945	0.417	81	110.4	243.5	62	84.5	[1]186.3
Totals					100.002	19,495	2,236.9	4,933.1	14,921	1,712.3	3,775.1
Totals for fish of 230 mm. and over					19.586	3,816	1,226.5	2,701.2	2,922	938.8	2,069.5

[1] Based on 240 bass seined and trapped in Periods 1 and 2.

TABLE 5

Data for the Estimation of the Bluegill Population of Salt Springs Valley Reservoir From Samples of Fish Seined and Trapped During August and September, 1951

Period	Days elapsed[1]	Minimum size handled (mm.)	Total number handled (A)	Total number marked and released	Total number marked at large (B)	Number of re-captures (C)
Seined fish only (LV clipped)						
1	0	70	969	968	0	1[2]
2	6	75	711	700	968	10
3	10.5	80	1,115	978	1,668	20
4	15	80	1,040	0	2,646	21
5	20	80	1,034	0	2,646	3
6	27	80	1,098	0	2,646	6
7	31.5	80	853	0	2,646	5
8	35.5	80	602	0	2,646	2
9	40.5	80	753	0	2,646	4
Trapped fish only (RV clipped)						
1	0	80	611	609	0	2[2]
2	5	80	570	546	609	2
3	9	80	519	499	1,155	3
4	13	80	523	97	1,654	0
5	19	80	567	0	1,751	3
6	26	80	214	0	1,751	0
7	30	80	598	0	1,751	7

[1] Computed from middle of 7-10 August period for seined fish and from middle of 7-11 August period for trapped fish.
[2] Not counted due to nonrandom sampling immediately after release.

As in the case of bass, discussed earlier, large numbers of rapidly growing young-of-the-year bluegills were continually being recruited to the population being sampled by the seine. A corrected estimate of the sort already described was therefore made, using the breaks indicated by arrows in the length-frequency histograms of Figure 5. This ill-defined break was chosen quite subjectively, although a similar break did appear when the data were grouped in several other ways. A fairly linear increase in length is shown in Figure 6 by plotting the lengths of the fish at the respective points indicated by arrows in Figure 5 against the times to the middates of the periods reckoned from Period 1. The least squares calculation of the slope of the line indicates a growth rate of 0.65 millimeters per day for the smaller bluegills during August and September.

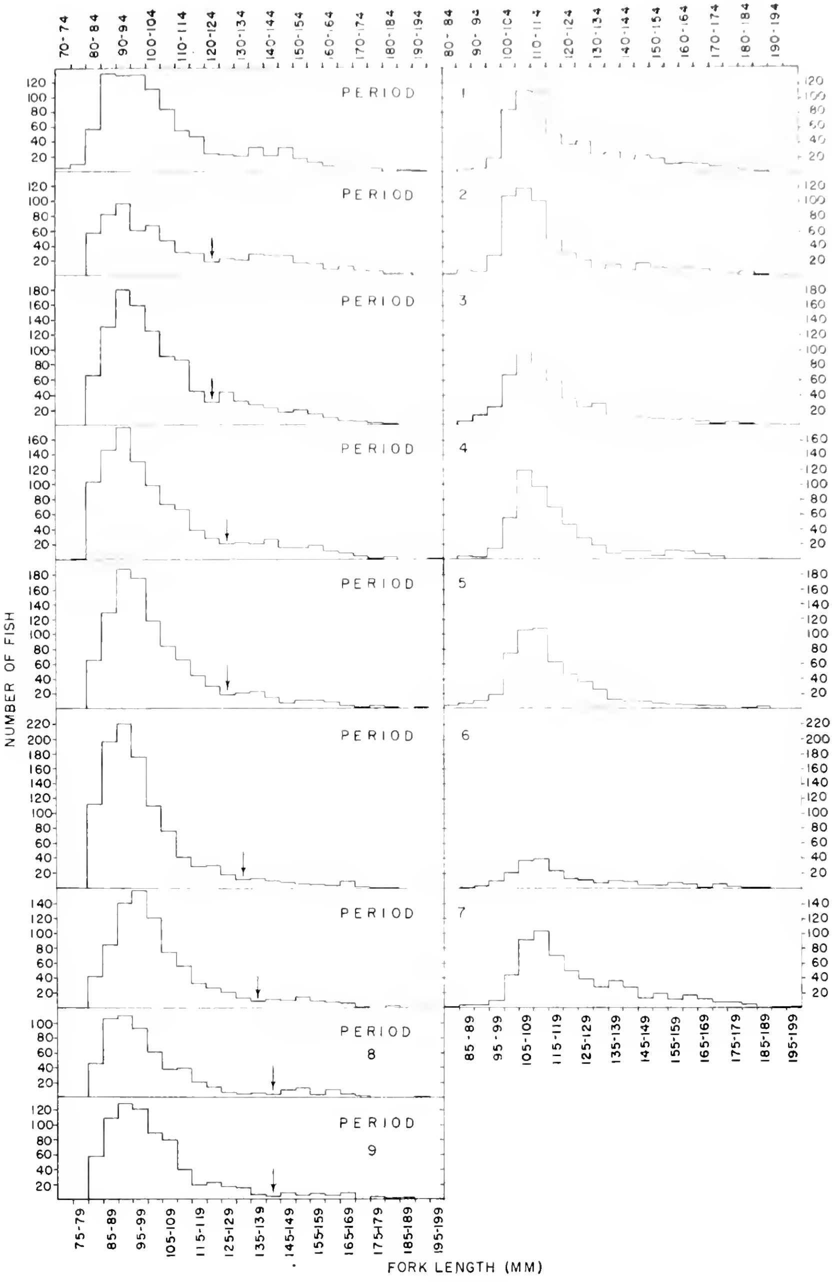

FIGURE 5. Histograms showing length frequency distributions of seined and trapped bluegills for each period of sampling in Salt Springs Valley Reservoir during August and September, 1951. The histograms on the left are for seine catches; those on the right, trap catches.

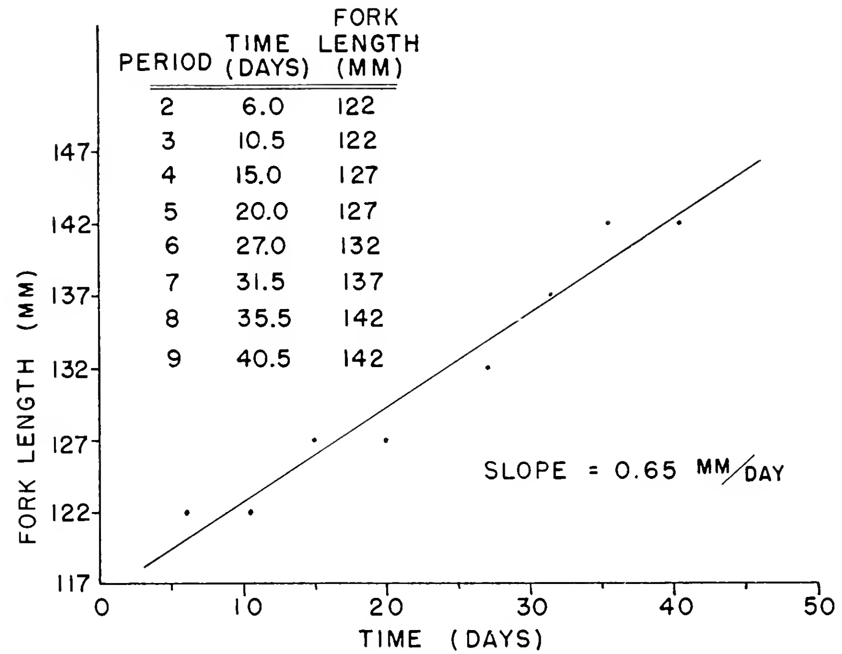

FIGURE 6. Data and diagram of progressive increase in bluegill lengths represented by a break in the length frequency histograms (Figure 5) used for rate of growth calculations

A good check on this growth rate can be obtained by plotting the lengths of the *smallest* recaptured bluegill taken in each period against the time at recapture, which had elapsed from the beginning of Period 4, when all marking had ceased. These data, shown in Figure 7, yield a slope (growth rate) by a least squares calculation of 0.72 millimeters per day—a very close agreement with 0.65 millimeters per day.

Corrections for growth of the small bluegills into the range of sizes taken by the seine were made on the basis of a minimum size of 85 millimeters fork length at Period 4. At the rate of 0.65 millimeters of growth

TABLE 6

Data for the Population Estimation of Seined Bluegills in Salt Springs Valley Reservoir Corrected for Recruitment With Summations From the Fifth and Following Periods

Period	Minimum size handled (mm.)	Total number handled (*A*)	Total number marked and released	Total number marked at large (*B*)	Number of recaptures (*C*)
1	75	965	964	0	1[1]
2	79	711	700	964	10
3	82	1,109	975	1,664	20
4	85	936	0	2,639	21
5	88	894	0	2,639	3
6	93	661	0	2,639	6
7	95	582	0	2,639	5
8	98	275	0	2,639	2
9	101	308	0	2,639	4

[1] Not counted due to immediate sampling after release.

PERIOD	DAYS ELAPSED FROM BEGINNING OF PERIOD 4	FORK LENGTH (MM) OF SMALLEST LV RECAPTURE
4	3	85
5	8	130
6	15	92
7	19	98
8	23	105
9	28	127

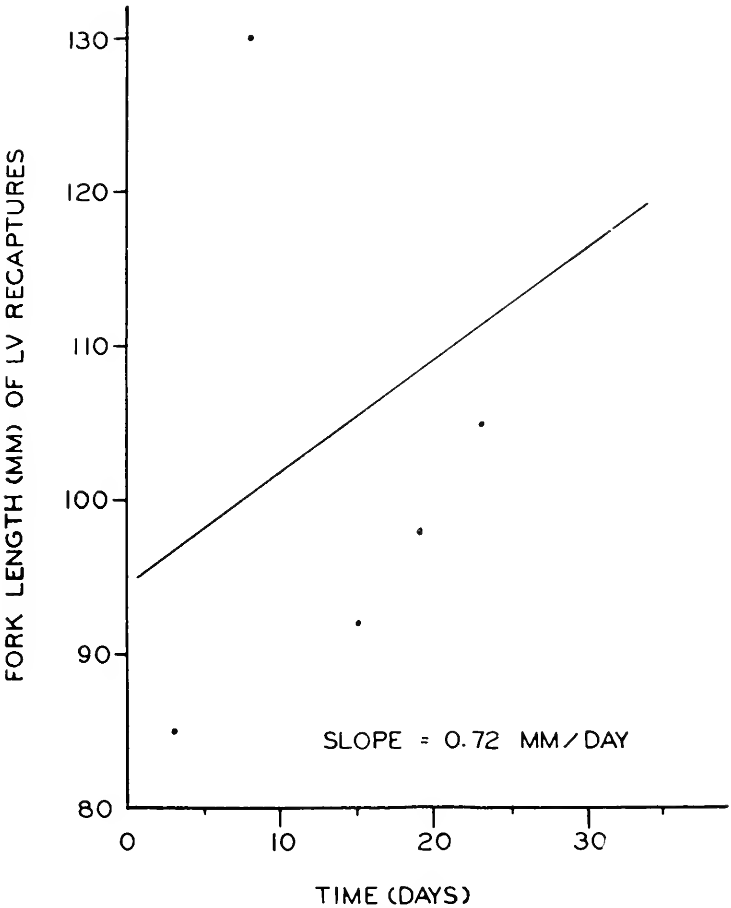

FIGURE 7. Increase in length as indicated for a series of the smallest recaptured bluegills taken within Periods 4 to 9 of the seining operations

per day, the corresponding minimum lengths at earlier periods were less than 85 millimeters, and the lengths for later periods were greater, as shown in Table 6. In this table capture-recapture data for seined bluegills revised to include only fish above these minimum lengths are also given. On the basis of the revised data from Periods 5-9,

$$\hat{P} = \frac{(B)\ \Sigma\ (A)}{\Sigma\ (C)} = \frac{(2,639)\ (2,720)}{20} = 358,904.$$

The 0.95 confidence limits are 215,630 to 554,866.

Population Estimates of Trapped Bluegills

It is of considerable interest to compare the bluegill estimates derived from seining and trapping. The capture-recapture data in the bottom part of Table 5 have been used to estimate the population of fish susceptible to trap capture. The resulting figure, uncorrected for recruitment over all the periods, would be

$$\hat{P} = \frac{\Sigma\ (A.B)}{\Sigma\ (C)} = \frac{4,226,246}{15} = 281,750,$$

with 0.95 confidence limits 154,258 to 469,113.

The numbers of recaptures among trapped RV marked fish (Table 5) indicate much more random capture-recapture sampling than for the seined fish. The relative randomness of the trap sampling was due to the setting of the traps and the releasing of RV marked fish over a much wider area than was initially possible for the seined fish.

This estimate has also been corrected for recruitment, using a growth rate of 0.65 millimeters per day, and starting with a minimum size of 85 millimeters during Period 1. The revised data are shown in Table 7.

TABLE 7

Data for the Population Estimation of Trapped Bluegills in Salt Springs Valley Reservoir Corrected for Recruitment

Period	Minimum size handled (mm.)	Total number handled (*A*)	Total number marked and released	Total number marked at large (*B*)	Number of recaptures (*C*)
1	85	611	609	0	2[1]
2	88	564	540	609	2
3	91	514	494	1,149	3
4	93	519	97	1,643	0
5	97	542	0	1,740	3
6	102	195	0	1,740	0
7	104	543	0	1,740	7

[1] Not counted.

This revision gives a figure of

$$\hat{P} = \frac{\Sigma\ (A.B)}{\Sigma\ (C)} = \frac{4,013,979}{15} = 267,599.$$

The 0.95 confidence limits are from 446,510 to 445,552. The resulting reduction in the estimate is negligible in contrast with the sizeable reduction in the case of seined bluegill.

Weight of the Bluegill Population

The fork length and weight relationships for a small, selected sample of 189 bluegills taken in August and September, 1951, are diagrammed in Figure 8. On the basis of a linear relationship between the logarithms of the fork lengths (L) in millimeters and the logarithms of the weights (W) in grams, a least squares equation of the relationship is

$$\log W = 5.33887 + 3.31138 \log L.$$

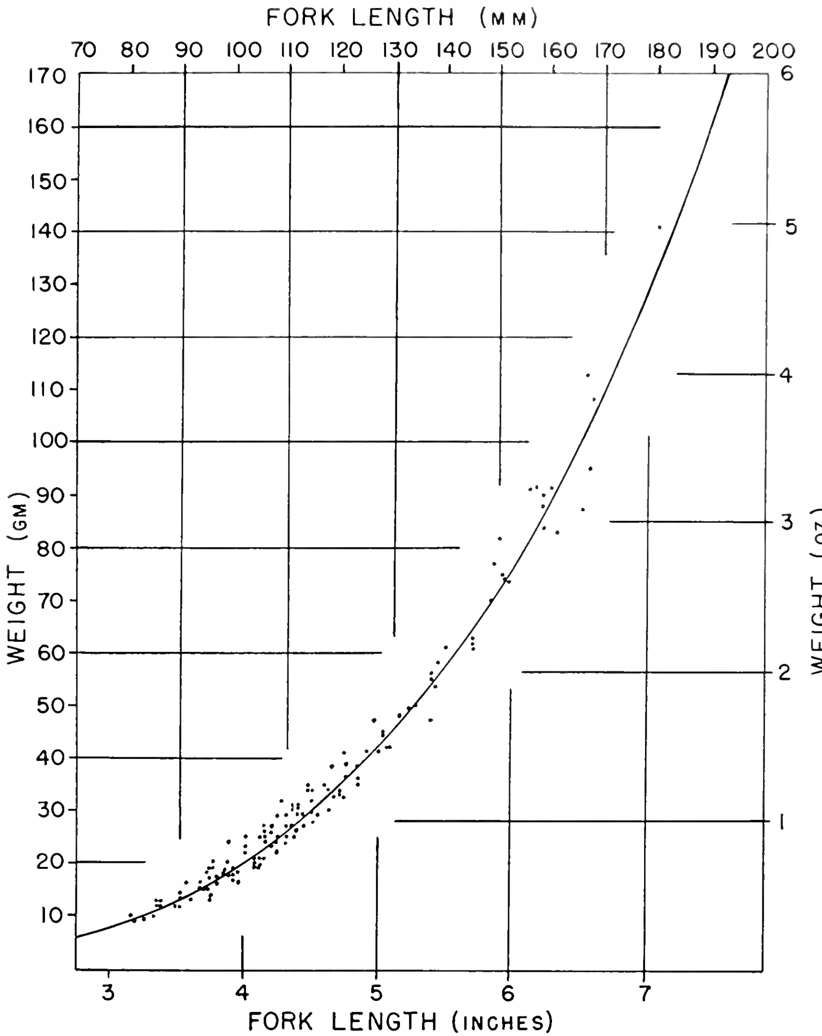

FIGURE 8. Length-weight relationships for bluegills taken in Salt Springs Valley Reservoir during August and September, 1951. The linear relationship is log weight in grams = −5.33887 + 3.31138 log fork length in millimeters.

TABLE 8

Breakdowns of the Uncorrected Population Estimate of 574,182 and the Population Estimate of 358,904 Corrected for Recruitment Into Numerical Frequencies and Calculated Weights of Seined Bluegills Within Five Millimeter Length Groups

Length class range (mm.)	Midclass length		Calculated average weight per fish		Percentage frequency of length class[1]	Population estimate of 574,182 uncorrected for recruitment and mortality			Population estimate of 358,904 corrected for recruitment only		
						Numerical frequency	Gross weight		Numerical frequency	Gross weight	
	(mm.)	(in.)	Grams	Pounds			(kg.)	(lbs.)		(kg.)	(lbs.)
70- 74	72	2.83	6.478	0.01128	0.413	2,371	15.4	33.9	1,482	9.6	21.2
75- 79	77	3.03	8.091	0.01784	0.929	5,334	43.2	95.2	3,334	27.0	59.5
80- 84	82	3.23	9.965	0.02197	5.888	33,808	336.9	742.8	21,132	210.6	464.3
85- 89	87	3.43	12.12	0.02672	13.636	78,295	948.9	2,092.0	48,940	593.2	1,307.7
90- 94	92	3.62	14.59	0.03217	13.326	76,515	1,116.4	2,461.5	47,828	697.8	1,538.6
95- 99	97	3.82	17.38	0.03832	13.429	77,107	1,340.1	2,954.7	48,197	837.7	1,846.9
100-104	102	4.02	20.53	0.04526	11.466	65,836	1,351.6	2,979.7	41,152	884.9	1,862.5
105-109	107	4.21	24.05	0.05302	8.677	49,822	1,198.2	2,641.6	31,142	749.0	1,651.1
110-114	112	4.41	27.98	0.06169	5.785	33,216	929.4	2,049.1	20,763	580.9	1,280.9
115-119	117	4.61	32.34	0.07130	4.752	27,285	882.4	1,945.4	17,055	551.6	1,216.0
120-124	122	4.80	37.14	0.08188	2.479	14,234	528.7	1,165.5	8,897	330.4	728.5
125-129	127	5.00	42.42	0.09352	2.376	13,643	578.7	1,275.9	8,528	361.8	797.5
130-134	132	5.20	48.21	0.1063	2.169	12,454	600.4	1,323.9	7,785	375.3	827.5
135-139	137	5.39	54.53	0.1202	3.409	19,574	1,067.4	2,352.8	12,235	667.2	1,470.6
140-144	142	5.59	61.40	0.1354	2.272	13,015	801.0	1,766.3	8,154	500.7	1,104.1
145-149	147	5.79	68.86	0.1518	3.409	19,574	1,347.9	2,971.3	12,235	842.5	1,857.3
150-154	152	5.98	76.92	0.1696	1.859	10,674	821.0	1,810.3	6,672	513.2	1,131.6
155-159	157	6.18	85.62	0.1888	1.446	8,303	710.9	1,567.6	5,190	444.4	979.9
160-164	162	6.38	94.99	0.2094	0.723	4,151	394.3	869.2	2,595	246.5	543.4
165-169	167	6.57	105.05	0.2316	0.619	3,554	373.3	823.1	2,222	233.4	514.6
170-174	172	6.77	115.83	0.2554	0.309	1,774	205.5	453.1	1,109	128.5	283.2
175-179	177	6.97	127.35	0.2808	0.309	1,774	225.9	498.1	1,109	141.2	311.4
180-184	182	7.17	139.66	0.3079	0.000	------	------	------	------	------	------
185-189	187	7.36	152.78	0.3368	0.206	1,183	180.7	398.4	739	112.9	248.9
190-194	192	7.56	166.72	0.3676	0.103	591	98.5	217.3	370	61.7	136.0
Totals			------	------	99.989	574,117	16,096.7	35,488.7	358,865	10,102.0	22,183.2
Totals for fish of 125 mm. and over			------	------	19.209	110,294	7,405.5	16,327.3	68,943	4,629.3	10,206.0

[1] Based on 968 fish handled in Period 1.

TABLE 9

Breakdowns of the Uncorrected Population Estimate of 281,750 and the Population Estimate of 267,599 Corrected for Recruitment Into Numerical Frequencies and Calculated Weights of Trapped Bluegills Within Five Millimeter Length Groups

Length class range (mm.)	Midclass length		Calculated average weight per fish		Percentage frequency of length class[1]	Population estimate of 281,750 uncorrected for recruitment and mortality			Population estimate of 267,599 corrected for recruitment only		
	(mm.)	(in.)	Grams	Pounds		Numerical frequency	Gross weight (kg.)	Gross weight (lbs.)	Numerical frequency	Gross weight (kg.)	Gross weight (lbs.)
85- 89	87	3.43	12.12	0.02672	0.4894	1,379	16.7	36.8	1,310	15.9	35.0
90- 94	92	3.62	14.59	0.03217	0.8157	2,298	33.5	73.9	2,183	31.9	70.2
95- 99	97	3.82	17.38	0.03832	3.0995	8,733	151.8	334.6	8,294	144.2	317.8
100-104	102	4.02	20.53	0.04526	13.7031	38,608	792.6	1,747.4	36,669	752.8	1,659.6
105-109	107	4.21	24.05	0.05302	17.7814	50,099	1,204.9	2,656.2	47,583	1,144.4	2,522.9
110-114	112	4.41	27.98	0.06169	17.6183	49,640	1,388.9	3,062.3	47,146	1,319.1	2,908.4
115-119	117	4.61	32.34	0.07130	8.4829	23,901	773.0	1,704.1	22,700	734.1	1,618.5
120-124	122	4.80	37.11	0.08188	6.0359	17,006	631.6	1,392.5	16,152	599.9	1,322.5
125-129	127	5.00	42.42	0.09352	6.6884	18,845	799.1	1,762.4	17,898	759.2	1,673.8
130-134	132	5.20	48.21	0.1063	3.9152	11,031	531.8	1,172.6	10,477	505.1	1,113.7
135-139	137	5.39	54.53	0.1202	4.2414	11,950	651.6	1,436.4	11,350	618.9	1,364.3
140-144	142	5.59	61.40	0.1354	2.7732	7,813	479.7	1,057.9	7,421	455.6	1,004.8
145-149	147	5.79	68.86	0.1518	3.5889	10,112	696.3	1,535.0	9,604	661.3	1,457.9
150-154	152	5.98	76.92	0.1696	2.9364	8,273	636.4	1,403.1	7,858	604.4	1,332.7
155-159	157	6.18	85.62	0.1888	1.6313	4,596	393.5	867.7	4,365	373.7	824.1
160-164	162	6.38	94.99	0.2094	1.7945	5,056	480.3	1,058.7	4,802	456.1	1,005.5
165-169	167	6.57	105.05	0.2316	1.6313	4,596	482.8	1,064.4	4,365	458.5	1,010.9
170-174	172	6.77	115.83	0.2554	1.1419	3,217	372.6	821.6	3,056	354.0	780.5
175-179	177	6.97	127.35	0.2808	0.8157	2,298	292.7	645.3	2,183	278.0	613.0
180-184	182	7.17	139.66	0.3079	0.4894	1,379	192.6	424.6	1,310	183.0	403.3
185-190	187	7.36	152.78	0.3368	0.3263	919	110.4	309.5	873	133.4	294.0
Totals					100.0001	281,749	11,443.1	24,567.0	267,599	10,583.5	23,333.4
Totals for fish 125 mm. and longer					31.9739	90,085	6,150.1	13,559.2	85,562	5,841.2	12,878.5

[1] Based on 1,183 fish handled in Periods 1 and 2.

The relative numbers of fish in each five millimeter group in the population at the outset of marking operations was determined, using 968 fish seined during Period 1 and 1,183 fish trapped during Periods 1 and 2.

Frequencies and weights of each length group are given in Table 8 for seined bluegills and in Table 9 for trapped bluegills. In each case total weights are given both for all sizes sampled and for fish roughly five inches or longer (125 mm. fork length). The latter are large enough to interest anglers.

Population of Carp

Carp data are summarized in Table 10 for seined fish plus a few trapped fish. After the fourth period, with 505 carp marked at large, marking was discontinued, and all carp sampled were removed from the lake. Using the 505 marked fish at the start of the Period 4, with corrections for subsequent removals of marked fish, the Schnabel estimate is

$$\hat{P} = \frac{\Sigma\,(A.B)}{\Sigma\,(C)} = \frac{613,142}{9} = 68,127.$$

Actually this estimate is biased downward slightly since removal of fish violates the basic tenet of the Schnabel method, which assumes a constant population. The 1,087 carp removed during the last sampling period have therefore not been included in the final estimate of 68,127, which has 0.95 confidence limits from 30,351 to 133,052.

The length frequency distributions of the seined carp, which comprise practically all of the fish handled, are given in Figure 9. These data indicate that all the carp handled were fully vulnerable to the seine or traps and recruitment corrections were therefore not necessary.

TABLE 10

Data for Estimation of Carp Population of Salt Springs Valley Reservoir During August and September, 1951, on Basis of Combined Seine and Trap Catches

Period	Total number handled (*A*)	Total number removed	Total number marked and released	Total number marked at large (*B*)	Number of recaptures (*C*)
1	115	0	115	0	0
2	171	0	171	115	1
3	223	0	219	286	2
4	152	152	0	505	1
5	345	345	0	504	2
6	129	129	0	502	2
7	225	225	0	500	3
8	236	236	0	497	1
9	137	137	0	496	0

TABLE 11

Fork Length and Weight Frequency Distributions of Salt Springs Valley Reservoir Carp Population Estimate of 68,127 From Combined Data of Trapped and Seined Fish

Midclass length		Percentage frequency of length class[1]	Numerical frequency of length class	Calculated average weight per fish		Gross weight of length class	
(mm.)	(in.)			(gm.)	(lb.)	(kg.)	(lb.)
134.5	5.30	0.200	136	17.2	0.104	6.1	14.1
144.5	5.69	0.200	136	58.0	0.128	7.9	17.4
234.5	9.23	0.200	136	235.4	0.518	32.0	70.5
244.5	9.63	2.196	1,496	265.2	0.585	396.7	874.6
254.5	10.02	6.387	4,351	297.8	0.657	1,295.7	2,856.5
264.5	10.41	11.178	7,615	332.9	0.734	2,535.0	5,588.7
274.5	10.81	10.778	7,343	370.5	0.817	2,720.6	5,997.9
284.5	11.20	5.589	3,808	410.8	0.906	1,564.3	3,448.7
294.5	11.59	3.393	2,312	454.0	1.00	1,049.6	2,314.0
304.5	11.99	0.998	680	499.9	1.10	339.9	749.4
314.5	12.38	3.593	2,448	548.8	1.21	1,343.5	2,961.9
324.5	12.77	8.184	5,576	600.7	1.32	3,349.5	7,384.4
334.5	13.17	11.776	8,023	655.8	1.45	5,261.5	11,599.6
344.5	13.56	8.184	5,576	714.0	1.57	3,981.3	8,777.3
354.5	13.96	8.184	5,576	775.6	1.71	4,324.7	9,534.3
364.5	14.35	4.790	3,263	840.4	1.85	2,742.2	6,045.5
374.5	14.74	2.994	2,040	908.8	2.00	1,854.0	4,087.4
384.5	15.14	2.595	1,768	980.7	2.16	1,733.9	3,822.6
394.5	15.53	1.597	1,088	1,056.2	2.33	1,149.1	2,533.3
404.5	15.93	1.397	952	1,135.3	2.50	1,080.8	2,382.8
414.5	16.32	1.198	816	1,218.3	2.69	994.1	2,191.6
424.5	16.71	0.599	408	1,305.2	2.88	532.5	1,174.0
434.5	17.11	0.798	544	1,395.9	3.08	759.4	1,674.2
454.5	17.89	0.798	544	1,589.6	3.50	864.7	1,906.3
474.5	18.68	.399	272	1,800.3	3.97	489.7	1,079.6
484.5	19.07	0.200	136	1,911.9	4.22	260.0	573.2
504.5	19.86	0.200	136	2,148.9	4.74	292.3	644.4
534.5	21.04	0.200	136	2,539.2	5.60	345.3	761.3
554.5	21.83	0.399	272	2,823.4	6.22	768.0	1,693.1
564.5	22.22	0.200	136	2,973.0	6.55	404.3	891.3
604.5	23.80	0.200	136	3,623.1	7.99	492.7	1,086.2
624.5	24.59	0.200	136	3,980.1	8.77	541.3	1,193.4
654.5	25.77	0.200	136	4,557.9	10.05	619.9	1,366.6
Totals____	_________	100.001	68,131	_____	_____	44,132.8	97,296.1

[1] Based on length frequency distribution of 501 carp seined during Periods 1, 2, and 3.

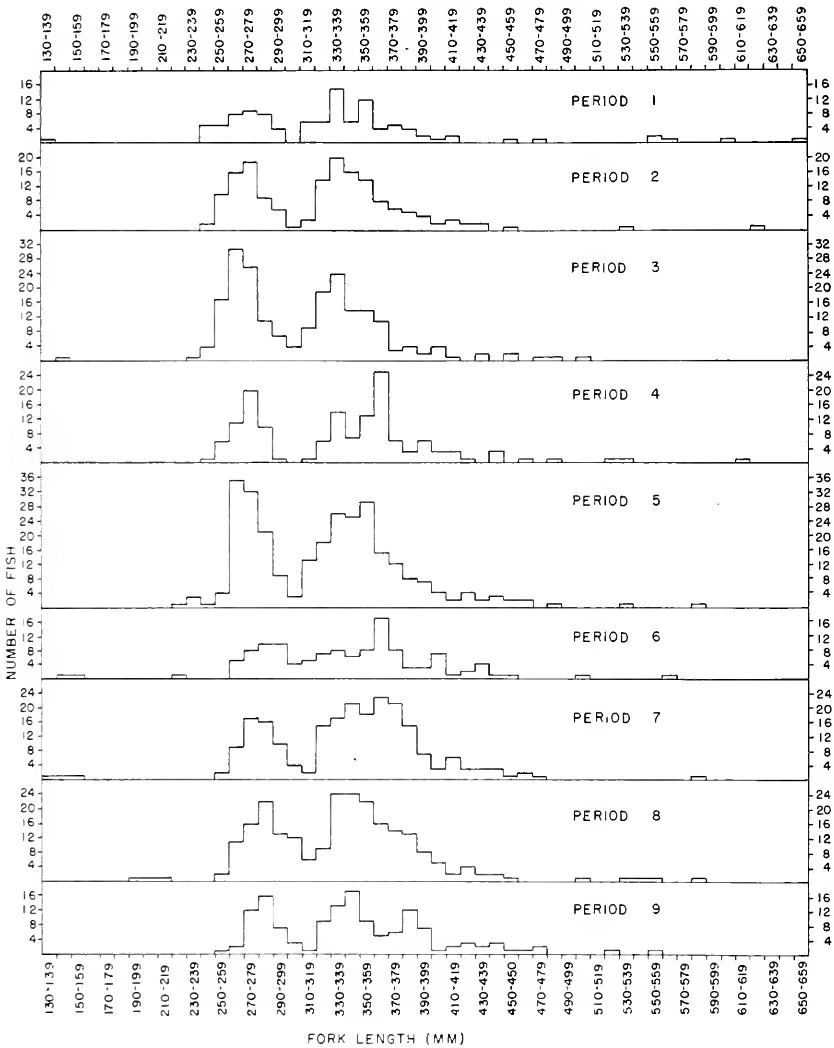

FIGURE 9. Length frequency histograms of carp seined during nine periods of sampling in Salt Springs Valley Reservoir during August and September, 1951

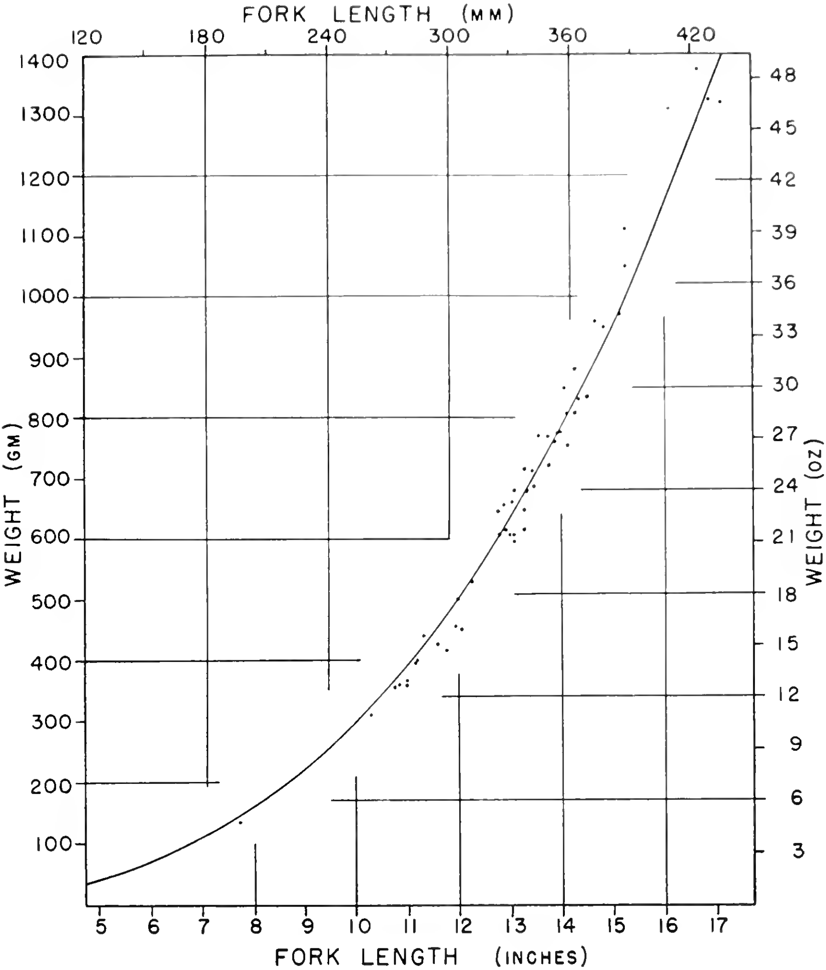

FIGURE 10. Length-weight relationships for carp taken in Salt Springs Valley Reservoir during August and September, 1951. The linear relationship is log weight in grams = —4.47455 + 2.88834 log fork length in millimeters.

Weight of Carp Population

The fork length-weight relationships of a small selected sample of 53 carp, illustrated in Figure 10, gave a least squares calculation of

$$\log W = -4.47455 + 2.88834 \log L,$$

where W is the weight in grams and L the fork length in millimeters. This was used to compute the average weight of the fish within each 10 millimeter length group, as shown in Table 11.

Population of Brown Bullheads

Because about 99 percent of the bullheads handled were large enough to be fully vulnerable either to the seine or the traps, it was possible to combine capture-recapture data for seined and trapped fish as shown in Table 12, which gives data from Period 4, when the first recaptures were taken. The appropriate Schnabel estimate, using these combined data, is

$$\hat{P} = \frac{\Sigma(A.B)}{\Sigma(C)} = \frac{30,848}{15} = 2,057.$$

The 0.95 confidence limits by Chapman's method are 1,126 and 3,424. The length frequency distribution of bullheads, to which the population estimate pertains, is shown in Figure 11.

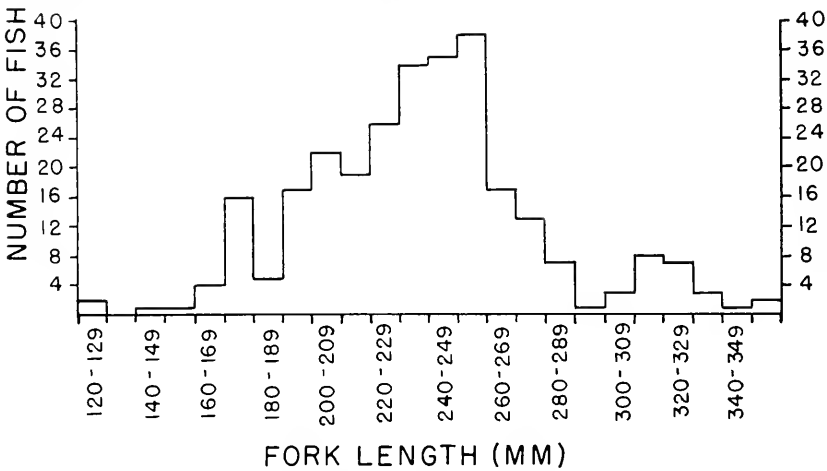

FIGURE 11. Length frequency distribution of brown bullheads taken during August and September, 1951, in Salt Springs Valley Reservoir

TABLE 12

Data for Population Estimate of Salt Springs Valley Reservoir Brown Bullheads on Basis of Combined Seine and Trap Catches

Period	Total number handled (*A*)	Total number marked at large (*B*)	Number of recaptures (*C*)
4	54	75	4
5	25	125	1
6	58	150	1
7	43	207	4
8	16	248	3
9	8	263	2

Recruitment corrections were unnecessary because of nearly complete vulnerability of the bullheads to the gear. It should be noted, however, that 20 traps lifted morning and evening caught about twice as many bullheads as did four daily seine hauls. Data were insufficient for making a crude weight estimate of the bullhead population.

Population of White Catfish

Over all periods of seining and trapping only 34 white catfish were taken. A single recapture out of 27 marked catfish at large appeared among six fish handled in Period 8, indicating that

$$\hat{P} = \frac{(A.B)}{(C)} = \frac{6 \cdot 27}{1} = 162.$$

The confidence limits from Chapman's data are from 12 to 3,157; actually, the 34 fish handled in the study would provide a more appropriate lower limit. It is manifestly impossible to obtain an adequate estimate of such a small and diffuse population with the scanty capture-recapture data. The length frequency distribution of the 34 white catfish is shown in Figure 12.

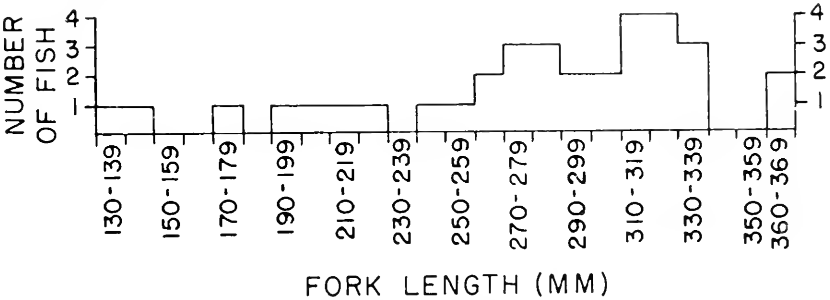

FIGURE 12. Length frequency distribution of white catfish taken during August and September, 1951, in Salt Springs Valley Reservoir.

Population of Golden Shiners

Sampling with the seine for the small golden shiners was inadequate, since only the larger fish were taken. A total of 161 was marked and released; none were recaptured. The length frequency histogram (Figure 13) indicates that the 161 shiners were the remnants of the four to six inch fish which had been stocked less than a year earlier, plus a few of their larger progeny. The spatial distributon of the shiner population in the reservoir was quite spotty and most of the 161 fish came from only a few hauls.

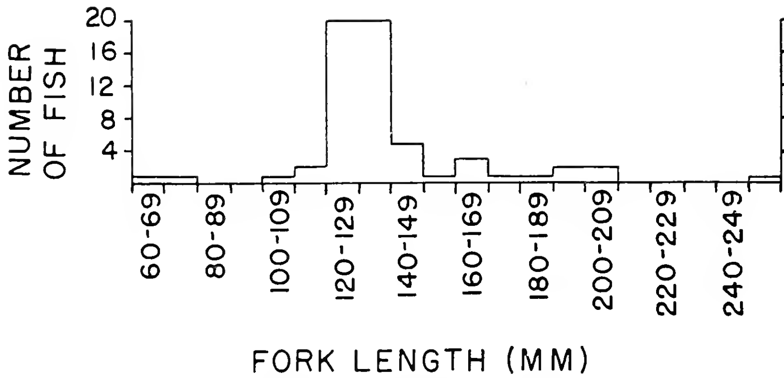

FIGURE 13. Length frequency distribution of golden shiners taken during August and September, 1951, in Salt Springs Valley Reservoir.

The golden shiner population must have been fairly substantial, judging from the facts that only the larger members were vulnerable to seining, that none of the marked fish was recaptured, and that the smaller and immature fish had apparently been successfully spawned and added to the population within the past year.

Populations of Other Species

Fairly large numbers of mosquitofish (*Gambusia*) were observed near the shores. They were too small to be sampled with the gear used in this study.

About 20 black crappies, all less than four inches long, were taken in the seine hauls. Occasionally appearing in the seine hauls were goldfish which weighed about a pound. About half the goldfish had skeletal deformities, indicating that their source may have been from goldfish culls, which are commonly used as bait. Single specimens of a greaser blackfish (*Orthodon microlepidotus*), an unidentified cottid, and a green sunfish (*Lepomis cyanellus*) were also taken during the August-September sampling.

SUMMARY OF POPULATION AND WEIGHT ESTIMATES

The Salt Springs Valley Reservoir estimates represent late summer populations in terms of the fork lengths indicated in the respective length frequency histograms.

For purposes of comparison with other bodies of water, the Salt Springs Valley Reservoir population densities may be expressed on either an areal or volume basis. Because the decreased volume or area at drawdown periods in fluctuating reservoirs may constitute a limiting condition on the size of fish populations, Wohlschlag (1952) suggested that it would seem appropriate to express population densities on a low water basis. In Table 13 the population and weight estimates on the basis of areas in surface acres and volumes in acre-feet for both the spillway level and the level at a normal drawdown, which is considered to be 12 feet below the spillway, are summarized.

TABLE 13

Summary of Estimates of Population Numbers and Crude Weights for Several Species of Fish in Salt Springs Valley Reservoir During August and September, 1951

Species	Gear used	Growth correction for recruitment of small fish	Population estimate	0.95 Confidence limits		Crude weight of population in pounds	Population densities per surface acre				Population densities per acre-foot			
				Lower	Upper		Spillway (900 acres)		Drawdown (412 acres)		Spillway (10,900 acre-ft.)		Drawdown (3,200 acre-ft.)	
							No.	Lbs.	No.	Lbs.	No.	Lbs.	No.	Lbs.
Bluegill	Seine	None	571,182	314,969	887,685	35,489	638	39.4	1,394	86.1	52.7	3.26	179.4	11.09
Bluegill	Seine	0.65 mm./day	358,901*	215,630	554,866	22,183	399	24.6	871	53.8	32.9	2.04	112.2	6.93
Bluegill	Traps	None	281,750	151,258	469,113	24,567	313	27.3	684	59.6	25.8	2.25	88.0	7.68
Bluegill	Traps	0.65 mm./day	267,599*	146,540	445,552	23,333	297	25.9	650	56.6	21.6	2.14	83.6	5.66
Largemouth bass	Seine and traps	None	19,501	15,881	23,347	4,933	22	5.5	47	12.0	1.8	.45	6.1	1.54
Largemouth bass	Seine and traps	0.77 mm./day	14,921*	12,139	18,282	3,775	17	4.2	36	9.2	1.4	.35	4.7	1.18
Carp	Seine and traps	None	68,127	30,351	133,052	97,296	76	108.4	165	236.2	6.3	8.93	21.3	3.04
Brown bullhead	Seine and traps	None	2,057	1,126	3,121	----	2	-----	5	----	0.2	-	0.6	-----
White catfish	Seine and traps	None	162	31	3,157	----	0.2	---	0.4	----	0.0	-	0.1	----
Bluegill (125 millimeters and larger)	Seine	0.65 mm./day	68,913			10,206	77	11.3	167	24.8	6.3	0.94	21.5	3.19
Bluegill (125 millimeters and larger)	Traps	0.65 mm./day	85,562			12,879	95	14.3	208	31.3	7.8	1.18	26.7	4.02
Largemouth bass (230 millimeters and larger)	Seine and traps	0.77 mm./day	2,922	----	-----	2,070	3	2.3	7	5.0	0.3	0.19	0.9	0.65

* Considered as best choice.

EVALUATION OF RESULTS

General

To make satisfactory population estimates by the Schnabel (1938) capture-recapture technique it must be assumed that the populations in question are constant in number and that random sampling of both marked and unmarked members is attained. These assumptions and their ramifications are discussed in detail by Ricker (1948, p. 39-52).

Differences Between Marked and Unmarked Fish

In this study there was no evidence to indicate any failure to recognize clipped fins on any species, nor was there any evidence to indicate that regeneration of clipped fins took place during the seven weeks of the study. So far as could be observed, there was no difference in the vulnerability of marked and unmarked fish to the gear, although the possibilities of differences would be expected had tags or other encumbering marking devices been utilized. Although there was no satisfactory check, marked fish were believed to survive as well as unmarked fish.

Random Distribution of Marked Fish and Random Sampling

The random sampling of the bluegill population in Salt Springs Valley Reservoir was a complex problem. The results of nonrandom distribution of seined (LV marked) bluegills and their subsequent recapture in seine hauls were especially noticeable until Period 5. During the first four periods they were seined in very restricted snag-free areas and released near the place of capture. As a result the number of recaptures in the first four periods was unusually high and population estimates were unusually low in comparison with the later periods, when seining localities and the release of seined bluegills were much more randomly distributed over the entire reservoir. By contrast, the traps, which were set in the more open waters, captured bluegills more nearly at random and the distribution of RV marked bluegills was quite broad at the outset of marking operations.

The bass and carp seemed to have a greater tendency to roam than bluegills; there was little evidence to suggest that marked fish of these species remained long at the point of release. Some evidence for the random distribution of marked bass came from observations of 9 marked bass among 69 taken by anglers April 5-6, 1952. For the ninth period of sampling in September, 1951, when 1,664 marked bass were at large, a sample of 108 bass yielded 16 recaptures. The proportion of marked bass in the two entirely different types of sampling are remarkably alike, considering the possibilities of mortality differences. This would tend to indicate that bass sampled in September were about as randomly distributed as they ever would be.

Catch data for brown bullheads and white catfish indicate that these small populations were fairly well distributed throughout the reservoir, although the capture-recapture data were too meager to indicate whether or not the marked fish were randomly distributed and resampled. Unfortunately, for most population studies there will be no *a priori* knowledge of fish movements and aggregation tendencies and there will be little opportunity to have a single type of gear which samples all parts of a body of water with equal efficiency. Even in small ponds Fredin

(1950) notes that nonrandom sampling of certain species can cause serious error in estimates by the capture-recapture method. For future large-scale capture-recapture operations it would be advisable to take extra precautions to insure both the random distribution of marked fish and the random distribution of sampling. The random distribution of marked fish could be assured by transporting and releasing them throughout the lake or reservoir, taking due precautions to prevent mortality from the extra handling.

Differential Vulnerability of Various Length Groups

Another type of nonrandom sampling bias results when different size groups of fish are taken in numbers not strictly proportional to the absolute abundance of the size groups. A bias of this sort appears especially when small fish which are not fully vulnerable to the gear are included in the mark-and-recapture tabulations. The effect of including incompletely vulnerable fish is to make the population estimates too low, as pointed out by Ricker (1948, p. 47). This type of bias might be suspected in the bluegill estimates from trap and seine data, in which the fish above the minimum sizes after recruitment corrections were somewhat too small to be fully vulnerable. It would have been much better to consider only those bluegills large enough to be included in the right limbs of the length frequency histograms in Figure 5; for trapped and seined bluegills such minimum fork lengths would have been about 115 and 95 millimeters, respectively. The differences in Tables 8 and 9 among the relative frequencies of the smaller length groups of bluegills taken in the two types of gear could, of course, be explained partly by mesh size differences. Differential vulnerability of various larger size groups of bluegills may have been the cause of the discrepancies of the numbers of fish estimated for comparable length groups, as summarized in Tables 8 and 9. Bluegills larger than 115 millimeters should have been large enough to have been taken in direct proportion to their abundance by either seine or traps. To test for discrepancies in relative frequencies of different length groups of seined and trapped bluegills, simple Chi-square tests of homogeneity were utilized. In order to have sufficient numbers of seined and trapped fish for comparisons, the fork length frequencies of fish over 115 millimeters taken during the first two periods were combined for the respective seine and trap catches. These data are set up in Table 14 with the appropriate "expected" numbers of fish which should occur if the seine and traps were nonselective over the indicated range of length groups. For the combined data of Periods 1 and 2, the very highly significant Chi-square of 36.33 ($P<0.001$) indicates that the frequency distributions for seined and trapped fish were not homogeneous; the traps caught disproportionately more fish in the 115-129 and, for the most part, in the 170-194 millimeter range; and the seine was generally more efficient than the traps in the 130-159 millimeter range. It has already been pointed out that seining during the first four periods was quite restricted areally in comparison with trapping, and it is quite probable that this bias was largely responsible for the differences in gear selectivity. During the later periods, when seining was much more randomized, it would be expected that size selectivity differences between seine hauls and trap catch would diminish. That this homogeneity did actually exist later

TABLE 14

Test of Homogeneity of Length-frequency Distributions of Seined and Trapped Bluegills Taken in Periods 1 and 2 (7-16 August, 1951)

Fork length (millimeters)	Seined fish		Trapped fish		Totals
	Observed	Expected	Observed	Expected	
115-119	78	92.3	102	87.7	180
120-124	43	58.0	70	55.0	113
125-129	47	56.4	63	53.6	110
130-134	43	39.0	33	37.0	76
135-139	64	53.9	41	51.1	105
140-144	50	38.0	24	36.0	74
145-149	61	51.8	40	49.2	101
150-154	36	32.8	28	31.2	64
155-159	31	25.7	19	24.3	50
160-164	15	18.0	20	17.0	35
165-169	19	19.0	18	18.0	37
170-174	9	9.7	10	9.3	19
175-179	8	7.7	7	7.3	15
180-194	7	8.7	10	8.3	17
Totals	511		485		996

Chi-square = 36.3329, df = 13, P = <0.001.

TABLE 15

Test of Homogeneity of Length-frequency Distributions of Seined and Trapped Bluegills Taken in Periods 6 and 7 (2-11 September, 1951)

Fork length (millimeters)	Seined fish		Trapped fish		Totals
	Observed	Expected	Observed	Expected	
115-119	62	64.9	92	89.1	154
120-124	57	50.2	62	68.8	119
125-129	41	38.4	50	52.6	91
130-134	27	25.7	34	35.3	61
135-139	23	28.7	45	39.3	68
140-144	23	24.4	35	33.6	58
145-149	19	15.2	17	20.8	36
150-154	21	18.1	22	24.9	43
155-159	14	13.9	19	19.1	33
160-164	12	14.3	22	19.7	34
165-169	16	12.2	13	16.8	29
170-174	3	6.7	13	9.3	16
175-199	4	9.3	18	12.7	22
Totals	322		442		764

Chi-square = 18.2124, df = 12, P = ca. 0.11.

on may be illustrated by comparing the length frequency distributions from combined data of Periods 6 and 7, as shown in Table 15. Here the Chi-square value is nonsignificant, although a great portion of the Chi-square is derived from the 170-199 millimeter range, in which the traps again seemed to be the more efficient gear. These comparisons between trap and seine catches do not indicate, however, which gear is the more unbiased; they indicate only that the two types of gear can differ in size selectivity. A seine of somewhat larger mesh would probably be more effective in taking bluegills in the larger size groups.

The discrepancies in the population estimates for bluegills of 125 millimeters and larger, shown in Tables 8 and 9, can be attributed to nonrandom distribution of marked fish, nonrandom resampling, and nonrandom length selection by the two types of gear.

For species other than bluegills, everything indicates that sampling was essentially at random. The fact that the larger bass observed in a creel check on April 5-6, 1952, had essentially the same proportion of marked fish as the bass of all sizes had during September, 1951, is a further indication that sampling and distribution of all of the size groups were random for this species.

If gear selectivity had varied for different size groups of any species, it would have been necessary to divide the samples into arbitrary size groups and mark each differently. The separate population estimates for the different size groups could then have been added for a total population estimate. Otherwise, the population estimate calculated by lumping all data would be too low (Ricker, 1948, p. 47-48).

Recruitment

During August and September there was a large recruitment of bass and bluegills at the lower limit of vulnerability to the gear. Estimates from an extended mark-and-recapture procedure under these circumstances are biased upward, because the smaller marked bass increase in vulnerability. In later samplings these small marked fish, even though now fully vulnerable, represent a disproportionately small fraction of fish in the size class compared to the proportions of marked fish in the larger size classes, which were vulnerable from the outset.

The bluegill population estimates would have been less biased due to recruitment had the initial minimum sizes been of the magnitude of about 95 and 115 millimeters for seined and trapped fish, respectively. The bass population estimates similarly would have been less biased due to recruitment had the initial minimum length been about 120 millimeters. With but rare exceptions all of the carp, brown bullheads, and white catfish were large enough to be fully vulnerable to either seine or traps, so that recruitment corrections were considered unnecessary.

The method of making the corrections for growth by following breaks in the bass and bluegill length frequency distributions (Figures 2 and 5) is admittedly arbitrary, although sufficiently accurate for the purpose. More adequate information on the magnitude of growth rates could come from detailed scale-growth studies or from studies based on growth records from individually marked fish—studies beyond the outlined scope of this investigation.

The importance of recruitment corrections are strikingly illustrated by a comparison of the corrected and uncorrected population estimates of bluegills (compare Tables 5, 6, and 7). The estimate from seined bluegill is reduced from 574,182 to 358,904, while the estimate from trapped fish is only reduced from 281,750 to only 267,599. The lesser reduction in the latter stems from the fact that the traps retained larger fish, which were not subjected to large recruitment from young-of-the-year fish as was the case with the seine samples. Had the studies continued for another month or so, the hordes of rapidly growing small bluegills would have grown large enough to affect the estimates from trap data also.

Bass recruitment in August and September presented problems similar to those for seined bluegills, and recruitment corrections lowered the estimate from 19,501 to 14,924.

Recruitment corrections could be circumvented in several ways in population estimation procedures involving rapidly growing small fish. A season of the year could be selected when the population would include only fish of sizes fully vulnerable to the gear. Wohlschlag (1952) noted that yearling bluegills, black crappies, and brown bullheads in Searsville Lake were, for practical purposes, fully vulnerable to the one-inch mesh wire traps during April and May. Another method of avoiding recruitment corrections would be to deal only with fish of fairly large sizes, say over five inches in length for bluegills and over eight or nine inches for bass; with fish of these sizes, the relative changes in vulnerability would be slower and population estimation could be carried out over a period of perhaps a month without recruitment corrections. Also, it might be possible to estimate populations during the winter months, when fish grow more slowly.

Before making any population estimates a preliminary large sample of each species of interest should be taken with each type of gear, in order to ascertain the length (or weight) frequency distributions of fish which should be large enough to be fully vulnerable to the gear in question.

Effects of Natural and Fishing Mortality

In the Schnabel type of estimation procedures, the loss of fish due to natural or fishing mortality tends to make the population estimate too great. The effects of fishing mortality could be accounted for only if there were an adequate estimate of the numbers of fish taken by fishermen during the capture-recapture operations. In Salt Springs Valley Reservoir a complete creel census would be needed only for bass caught in the spring and early summer. At other seasons, the numbers of all species taken by anglers are so small that they would be negligible compared to those taken in the capture-recapture operations. For this reason the estimates in this reservoir were conducted in late summer. Similar circumstances prevail in many of the warmer waters of California.

The occurrence of natural mortality, on the other hand, occurs throughout the year at varying seasonal rates. In this study attempts were made to correct for bass and bluegill mortality by accounting for the decrease in numbers of the marked fish at large. They were unsuccessful because there too few capture-recapture periods to follow the trend of successively increasing population estimates. In the case of the seined bluegill data for Periods 4 to 9, a mortality rate of about 0.8 percent per day was obtained, although the inclusion of the nonrandomly sampled Period 4 data made this value a purely arbitrary one. At this rate the fish would experience a seasonal mortality of about 88 percent over a period of 250 days—a rather high rate. (See Ricker, 1944, for a discussion of instantaneous and seasonal mortality rates.) By adjusting the recruitment-corrected data so that the marked fish were removed at this arbitrary rate of 0.8 percent per day, the estimate of 358,904 is reduced to 298,544. Similarly, the recruitment-corrected estimate for trapped bluegills is reduced from 267,599 to 238,413.

The recruitment-corrected bass population estimates showed a general tendency to increase from period to period to the extent that a daily mortality of about 3 percent would be required to correct the tendency.

At this rate, the seasonal mortality on a 250-day basis would be about 95 percent—a most unlikely high rate, which would reduce the estimate of 14,924 to around 10,500 bass. The effects of more reasonable mortality rates were also calculated: at a rate of about 1 percent per day (corresponding to over 90 percent for a 250-day season), the 14,924 estimate would be reduced to about 12,900; at a mortality rate of about 0.35 percent per day (corresponding to 58 percent over a 250-day season), the 14,924 estimate would be lowered to about 14,200.

The obvious conclusion from these laborious adjustments is that the small corrections attained are not worth the effort for capture-recapture operations lasting five or six weeks.

Evaluation of Weight Estimates

The weight estimates involve a series of calculations in which propagated errors could have occurred. The more important are errors of population estimates, errors associated with length-weight data based upon small, selected, and independent samples of fish, errors in length frequency histogram data due to sampling biases, and errors associated with recruitment corrections. It must be emphasized that the calculated weights of the various populations are only gross approximations.

MANAGEMENT PROBLEMS IN SALT SPRINGS VALLEY RESERVOIR

Largemouth Bass

If the guesses that 5,000 to 8,000 bass were taken by anglers in the 1951 spring season were reasonable, it is obvious that the population is very heavily exploited. Assuming that about half the estimated 15,000 remaining after the 1951 fishing season survived to the spring of 1952 and that the fish were large enough to be taken by anglers, it is also obvious that most of the larger bass would be removed. That extensive exploitation of the larger bass during the spring of 1951 actually existed is suggested by the very common occurrence of hook wounds which were observed on most of the larger seined bass in the late summer of 1951.

Since the 1951 bass population was a "young" population it could possibly increase in numbers for several more years with present mortality rates and with continuing spawning successes. However, it would be doubtful if very many older "lunker" bass would ever exist at the present high rate of exploitation. Furthermore, a spawning failure in any one year could cause a great decline in the fishery during the following year, because the yearling bass (9 to 10 inches long) make up a large part of a normal catch, and they would be largely absent after a spawning failure in the previous season.

At the present time food relationships of the bass to their prey are not well understood, although indications are that the bluegills are the principal forage. If the young-of-the-year bluegills grow at the usual rates for warmer waters, most of them would be too large to be eaten by the smaller yearling and young-of-the-year bass by late autumn. This has been observed to be the case in autumn samplings of the fish in the reservoir. The introduction of a small species of forage minnows might well facilitate the growth of the smaller bass during the late summer through the following spring, and result in considerably more yearling bass being recruited into the population supporting the sport

fishery. The recently introduced golden shiners may accomplish this in Salt Springs Valley Reservoir, although this will have to be evaluated in the future in terms of increased growth rates and population numbers of their predators.

Bluegills

The bluegill population has grown remarkably from the original stocking in 1947-48. From the data of Figure 5 and Tables 8 and 9 it may be observed that there are now relatively few bluegills large enough to interest anglers. The growth rate of 0.65 millimeter per day for the small bluegills during late summer is quite high compared with many of the data compiled by Carlander (1950), but this rate itself is misleading. A cursory examination of bluegill scales indicated that the small fish do in fact grow rapidly. But the three- and four-year-old fish have scale annuli very close together and it is quite obvious that the larger bluegills are stunted.

Which of the larger benthos and fish forage were available to the adult bluegills is not known definitely, but a few stomach examinations revealed that they ate small bottom fauna, as did the younger bluegills. Undoubtedly the very abundant carp also compete with the bluegills for elements of the bottom fauna. Under present conditions there would be little small fish forage available to the larger bluegills except in the spring when bluegill and bass fry are present.

The chief value of bluegills in Salt Springs Valley Reservoir seems to be as forage for bass and the immediate question could be raised as to whether or not species such as golden shiners or other small minnows would provide better year-round bass forage. Observations of anglers during spring and summer of 1951 revealed that bluegills were only slightly exploited, although a few fishermen made large catches.

Because there is some doubt of the value of bluegills as the ideal bass forage and because the larger bluegills appear to be stunted and of little importance to anglers, the over-all desirability of stocking bluegills in a reservoir of this type should be reviewed very critically in the future.

Carp

The rapid build-up of the carp population of Salt Springs Valley Reservoir from supposedly no fish at the time of poisoning in 1947 has been quite phenomenal. Although the carp outweigh all of the other species combined, they are of no importance to the anglers, and because of their rapid growth to large sizes, undoubtedly they are of little value as bass forage.

The effects of carp on bass and bluegills may only be surmised. They probably compete very successfully with bluegills for elements of the bottom fauna, and their feeding and spawning habits probably interfere with spawning of the more desirable species.

Ideally the entire carp population should be replaced either with sport species or with species which are more efficient in supporting bass production, since bass are *the* sport species of the reservoir. The possibilities of carp extermination in the reservoir could be realized only if complete extermination over the entire watershed were possible and if subsequent reintroductions were prevented.

Commercial carp removal could be effective in reducing the quantity of carp only if the rate of exploitation were high and continuous. While the sporadic removal of an accumulated stock of carp might be economically profitable, the removal would be ineffective should the population rapidly grow back to former proportions. On the other hand, continuous commercial operations designed to keep the population at a low level would be less profitable than sporadic operations on a catch per unit of effort basis.

Other Species

The only other species of any importance to anglers at the present time in Salt Springs Valley Reservoir are brown bullheads and white catfish. Apparently these catfishes survived the 1947 poisoning. That continued spawning success for these species has occurred is evident from observations of fingerlings and good size distributions as indicated in Figures 11 and 12. It is possible that both species do, to some degree at least, occupy the carp niche. It is also possible that the catfishes could reach the high proportions in which they compete with centrarchids noted in Searsville Lake (Wohlschlag, 1952). They therefore warrant serious consideration in future reservoir stocking programs.

The golden shiner population deserves special mention, since it is the only strictly forage population of any consequence. Because they are relatively small, their forage value should be high for predators of all sizes. While no information exists on the comparative value of the young-of-the-year of this species over bluegills as bass forage, it may be presumed that the small size of the shiners would render them more valuable forage than bluegills for the small bass during autumn and winter. There are undoubtedly other small minnows which could also fulfill bass forage requirements.

If the reservoir is ever poisoned again for complete fish removal, restocking only with golden shiners and/or other small minnows with bass is recommended. Then, if the minnows support an adequate bass population, bluegills and possibly black crappies could be stocked later if there was enough surplus forage to insure their rapid growth.

SUGGESTED PROCEDURE FOR FISH POPULATION ESTIMATES IN LARGER BODIES OF WATER

Experience gained in this exploratory study has shown that adequate Schnabel type population estimates for the more abundant and larger species can be made in from two to four weeks with a crew of four men. The method is applicable to waters up to about 3,000 acres, with populations of about three times the magnitude of those of Salt Springs Valley Reservoir, provided they are suitable for seining.

Operations should coincide with a period of low angling intensity, so that populations can be considered "constant." Even with a high rate of natural mortality, corrections will have little effect on estimates based on four weeks of sampling, as mentioned earlier.

Since the seine sampled all of the common species in Salt Springs Valley Reservoir as well as or better than the traps, seining is recommended over trapping for general use.

Mesh sizes should be chosen to avoid inclusion of large numbers of small, rapidly growing fish to obviate recruitment corrections. It has been pointed out that recruitment corrections for bluegill population estimates were much less for trapped fish than for seined fish, since the larger mesh size of the traps resulted in catches of larger, slower-growing bluegills. This information suggests that a seine having about two-inch stretched mesh could have been used; such a seine 300 feet long, 15 feet deep in the middle, and tapered to 6 feet deep at the ends can be handled readily by four men. At the outset of sampling operations, size frequency histograms should be constructed for each species to determine the minimum sizes which are fully vulnerable to the gear, and only the sizes of fish included in the right limbs of the size frequency histograms should be used for the capture-recapture data. For most rapid estimates, in which only the larger sizes of fish of interest to anglers are to be included, the lower length limit of species with more compressed forms (e.g., bluegills) would be about five or six inches, while the lower length limits of more fusiform species (e.g., largemouth bass) would be about eight or nine inches. With minimum sizes like these, recruitment corrections for studies lasting a month or less would ordinarily be small enough to ignore. The same preliminary sampling of fish could also be used to provide weight data, so that the average weight of fully vulnerable fish could be computed.

The results of the bluegill studies indicate that serious errors in population estimates occur when the marked fish are not randomly distributed. Because there will usually be inadequate *a priori* information on the nature of fish distribution, marked fish should be released throughout the body of water and sampling should be as random as possible.

The continuous marking procedure is to be recommended over the procedure of initially releasing a large number of marked fish, since it is quite possible that the initial release may turn out to be too small and that sampling will have to be carried out over too long a period in order to obtain enough recaptures for narrow confidence limits. For studies lasting much over a month, recruitment and mortality corrections may have to be considered. Continuous marking operations have the further advantage that more marked fish are eventually released for the same amount of sampling effort and that marking operations can be discontinued for any one species as soon as an adequate estimate is obtained.

SUMMARY

Population estimates by the Schnabel mark-and-recapture method were obtained for the principal fish species in 900-acre Salt Springs Valley Reservoir, Calaveras County. These estimates with 0.95 confidence limits, crude weight estimates, and densities on areal and volume bases are summarized in detail in Table 13. The principal conclusions are:

1. The principal game species is the largemouth black bass. The late summer population, after the heavy and efficient spring exploitation, was estimated to be 15,000 fish four inches or more in length. Most of these fish which survive until the following spring and summer would be expected to be of catchable size. Of the 15,000 bass present in late summer, about 2,900 weighing around 2,000 pounds were estimated to be over nine inches long.

2. The best estimate of the bluegill population from seining data was about 358,900 fish longer than approximately three inches; of these, it was estimated that around 68,900 weighing about 10,200 pounds were longer than five inches. The best estimate of the bluegill population from trapping data was approximately 267,600 fish longer than about three and a half inches; of these, it was estimated that around 85,500 weighing about 12,900 pounds were longer than five inches. Although the smaller bluegills grow fairly rapidly for a time, the adults grow very slowly. Presumably there is inadequate forage for the larger fish.

3. The carp population was estimated to include about 68,100 fish weighing approximately 97,300 pounds—a weight greater than that for all of the other species combined.

4. Brown bullhead and white catfish populations are small and unimportant to fishermen. The catfish populations appear to be permanently established.

5. The golden shiner population has quite possibly become established within one year after the introduction of adults, judging by the presence of young-of-the-year fish.

The problems of management of the fishery resources in Salt Springs Valley Reservoir have been evaluated in terms of the sizes of fish populations and their value to anglers. The crux of these problems is the maintenance and, if possible, the increase of the production and yield of largemouth bass. Bluegills, the principal bass forage, are of little value to anglers due to the small size of adult bluegills; and carp, whose forage value to bass is doubtful, are of no value to fishermen. Ideally, greater bass production could be realized if the carp were completely removed and their niche occupied by small minnows of value as bass forage. Removal of carp might also allow for an increased rate of growth for adult bluegills. A large population of small minnows might ultimately support good bluegill and black crappie populations in addition to black bass; if not, the value of stunted bluegills and black crappies is greatly to be questioned.

It has been concluded that the continuous mark-and-recapture method is practicable for estimating warm-water fish populations in moderately large reservoirs or lakes at seasons when fishing pressure is negligible. It is believed that estimations of adult populations in bodies of water up to about 3,000 acres can be made by a four-man crew utilizing a large seine continuously for two to four weeks. The greatest obstacle in obtaining accurate estimates would appear to be nonrandom distribution and resampling of marked fish. Errors of recruitment and mortality should provide no great obstacles and can be disregarded, provided only adult fish are sampled and provided the estimation procedures lasts a month or less.

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THE JACK MACKEREL, *TRACHURUS SYMMETRICUS*: A REVIEW OF THE CALIFORNIA FISHERY AND OF CURRENT BIOLOGICAL KNOWLEDGE[1]

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INTRODUCTION

The jack mackerel, *Trachurus symmetricus* (Ayres), a member of family Carangidae, occurs along the Pacific Coast of North America from British Columbia south at least into the southern half of Baja California, Mexico. It has been captured nearly 500 miles off the coast of California. Despite this extensive range, the fishing grounds are confined largely to inshore waters from central California south to the Mexican boundary. By far the largest tonnages are taken in Southern California waters, and catches are most unusual north of Monterey Bay. Small quantities have been taken off the Oregon coast, where the fish are said to occur regularly in the summer (Cleaver, 1951, p. 29). The fishery is prosecuted almost entirely by boats using roundhaul gear, particularly purse seines. Virtually the entire catch is canned.

Until 1947, this fish was of minor commercial importance. In 1947 it emerged as a major variety, and has remained among the leaders since that year. Its sudden rise and continued high rank are attributable in a large part to the series of poor seasons experienced by the sardine and Pacific mackerel fisheries (*Sardinops caerulea* and *Pneumatophorus diego*). (The present status of these fisheries is discussed by Clark, 1952, and Fitch, 1952.) In the earlier years, the seiner fleet sought sardines primarily and Pacific mackerel when they were available or when the

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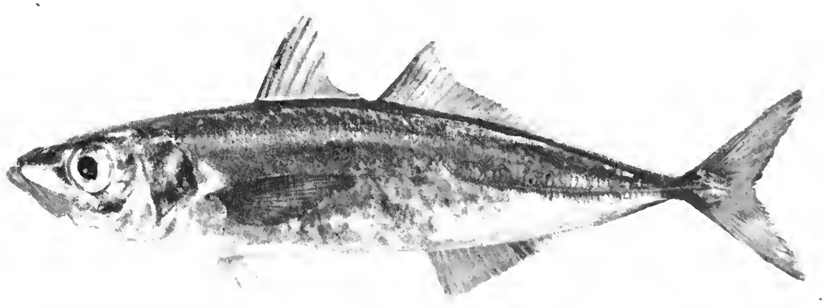

FIGURE 1. The jack mackerel, *Trachurus symmetricus*

sardine season was closed. Jack mackerel catches were in a large part accidental. Jacks are still less highly regarded than are the other two but they remain available on the fishing grounds.

Another factor affecting the fishery's rise, the importance of which cannot be properly assessed, is the increased use of depth-sounding devices as a fishing aid. These were first installed on California seiners in 1944 (Daugherty, 1952, p. 130) and within two or three years were virtually standard equipment. The rise of the jack mackerel fishery thus occurred at the time this equipment was first widely employed and there is a certain amount of evidence to show that jack mackerel tend to school somewhat below the surface so that they are often not observed by visual scouting. If this schooling habit can be confirmed, it would help explain the low catches of the earlier years. For even though these catches were largely accidental, one would anticipate that the total tonnage caught would have been greater if the fish had been as available to the fishermen as they are at present. An alternative explanation is, of course, a rise in abundance of jack mackerel concurrent with the decline of sardines and Pacific mackerel.

COMMON NAME

The name "jack mackerel" dates only from 1947 and first appeared in print in 1948 (Roedel, 1948, p. 10, 57). Prior to that time, the fish was known as either "horse mackerel" or "Spanish mackerel," the former predominating in the northern part of the State and the latter in the southern. "Horse mackerel" appears most frequently in the literature and had been recognized as the official common name in California (Walford, 1931, p. 81). This name was in use in San Francisco as early as 1878 (Lockington, 1880, p. 34). "Spanish mackerel" was noted by Smith (1895, p. 231) as the prevalent name in San Pedro in 1894.

The official name "horse mackerel" was not subject to any criticism during the years of a minor fishery, and, whatever else may be said, did reflect popular usage. However, the industry found the name a handicap in marketing an increased pack, and in the summer of 1947 the Department (then Division) of Fish and Game undertook a survey of the industry in an attempt to select a name more suitable for labeling purposes. The concensus favored "jack mackerel" and this name was given official sanction. As a result, the United States Pure Food and Drug Administration gave its permission to use the name on labels in May, 1948 (Roedel, 1949a, p. 31; 1949b, p. 204). This coined name has entered the vernacular remarkably rapidly and appears well on the road to supplanting the old.

There is an interesting postscript to the adoption of "jack mackerel." The May, 1950, issue of *Fisheries Newsletter* (p. 14), an official Australian publication, carried an announcement that "scad, formerly known as horse mackerel and cowanyoung, from now on will be Jack Mackerel. The scientific name is *Trachurus novaezelandiae*." The change was suggested by the Commonwealth Director of Fisheries and accepted by the Australian states, fisheries authorities, and the canners' association because the name "scad" had been found unsatisfactory for marketing purposes. "In addition," continues the notice, "a very closely related

species known as Jack Mackerel was taken in California waters, and it was possible that the Australian canned scad would be competing on the same market as the California fish. The name 'Jack Mackerel' would not only have a greater appeal on the local market but would also be known on the overseas market."

THE FISHERY PRIOR TO 1926

The early history of the jack mackerel fishery is at best obscure. Records are scanty for the years prior to 1926 and often mention simply "mackerel"—meaning either jack or Pacific or both. There are, however, interesting bits of information included in some of the early reports on the fisheries of the Pacific Coast. Among these surveys was that conducted by W. N. Lockington, who was employed by the California Commissioners of Fisheries to investigate the fishes found in the San Francisco markets during the period October, 1878–September, 1879. His report (1880), which, as noted, listed the common market name as horse mackerel, included these remarks (p. 35): "This fish is only sent occasionally to our market, usually from Monterey, but when it is present it is in greater abundance than any of the other *Scomberoids*. Occasionally it visits the Bay of San Francisco, for the single specimen (17 inches long) on which Dr. Ayres founded his species, was taken there, and the dealers assure me of its occasional occurrence. Those sent from Monterey are seldom as large as Ayres' specimen. It is not valued so highly as either of the previous species [pompano, *Palometa simillima*, and Spanish mackerel, *Scomberomorus concolor*]." In another report, also prepared for the Commissioners of Fisheries, Lockington (1881, p. 39) wrote this: "... the horse mackerel is an old friend of the Levantines who carry on here [San Francisco] the same occupations they pursue in the Mediterranean. Occasionally it strays up the coast as far north as San Francisco. It is taken in large numbers in seines, and salted for bait."

Taking part in a nation-wide survey of American fisheries, Dr. D. S. Jordan, in company with Dr. C. H. Gilbert, spent the year 1880 on the Pacific Coast. His reference to jack mackerel was brief and is here quoted from Goode (1882, p. 36): "... In California, according to Jordan, it is an abundant species, and is there commonly known as the Horse Mackerel. He remarks: 'It reaches a length of about a foot and a weight of less than a pound. It ranges from Monterey southward, appearing in the summer, remaining in the spawning season, and disappearing before December. It arrives at Santa Barbara in July, and at Monterey in August. In late summer it is exceedingly abundant. It forms part of the food of larger fishes, and great numbers are salted for bait. As a food-fish it is held in low esteem, but whether this is due entirely to its small size we do not know ....'" Substantially the same quotation is the only reference to jack mackerel contained in the multivolume report later issued on the fishing industry of the United States (see Goode, 1884, p. 326).

Collins (1892), reporting on another survey of Pacific Coast fisheries made in 1888 and 1889, listed "horse mackerel" as a commercial variety in Los Angeles and Santa Barbara Counties but gave no catch figures. He reported that, in San Luis Obispo County, jack mackerel were taken in drift nets and to a lesser degree trolling, the fishery reaching a peak

in the summer. Port Harford (now Port San Luis) shipped 1,500 pounds of salted jack mackerel valued at $90 in 1888. He mentioned jack mackerel as present in Monterey Bay from July to October but rarely found farther north. In discussing the fisheries of San Francisco, Collins wrote (p. 121): "[It] averages 3 pounds in weight . . . and is in the market most of the year. The price ranges from 8 to 20 cents per pound. Professor Jordan . . . says its weight is less than a pound and in 1879 found it to be held in low esteem as a food-fish, though he did not know whether this was due entirely to its small size. The estimation of its value seems to have changed materially in the past decade." A tabulation of San Francisco's fresh fish trade in 1888 and 1889 shows larger sales of jack mackerel than of Pacific but at a lower retail price. Similar data for 1890-1892 are given by Wilcox (1895, p. 209) and the five years are summarized in Table 1. We note a sharp decline in jack mackerel sales with a constant average retail price; a less marked decline with an increase in price for Pacifics.

TABLE 1

Sales of Jack and Pacific Mackerel in the San Francisco Market, 1888-1892
Data From Collins, 1892, and Wilcox, 1895

Year	Jack mackerel		Pacific mackerel	
	Pounds	Average retail price	Pounds	Average retail price
1888	100,000	$0.08	25,000	$0.10
1889	125,000	.08	30,000	.125
1890	75,000	.08	20,000	.13
1891	40,000	.09	15,000	.15
1892	15,000	.08	10,000	.15

Wilcox's (1898) report on the Pacific Coast fisheries of 1895 showed a catch of "horse-mackerel" totaling 118,530 pounds valued at $1,386. (Pacific mackerel landings were 90,390 pounds valued at $2,637 this same year.) Of this, 98,530 pounds worth $986 was landed in Los Angeles County while Santa Cruz County accounted for the remaining 20,000 pounds worth $400 (p. 650, 652).

The first reference to canning is found in Smith (1895) who made a survey "for the purpose of making a study of the apparatus and methods of the fisheries of that region [the Pacific Coast]" in May and June, 1894. By way of background, in December, 1893, a sardine cannery opened in San Pedro. It was the second plant outside of the salmon industry to operate in the State, one which handled sardines and anchovies having operated in San Francisco from June, 1889, until August, 1893 (Scofield, 1951, p. 26). To quote Smith (p. 231):

"In connection with the capture and canning of sardines at San Pedro, a species of carangoid fish . . . is taken and utilized to some extent for canning and salting. At San Pedro it is known as 'Spanish mackerel'; at other places on the coast it is called 'horse mackerel.' . . .

"At San Pedro these fish are taken in the small steam vessel used for sardine fishing. A special purse seine, 135 fathoms long and 100 feet

deep, with a two-inch mesh, is used. The fish are caught in San Pedro Bay and around the Catalina Islands. They go in schools of varying sizes. Some large hauls are made; thus in the fall of 1893, 150 barrels were taken at one set near the Catalina Islands.

"The fish caught are mostly of small size. According to the statements of the gentlemen connected with the California Fish Company, the largest taken in their seine are 12 or 14 inches long, the smallest are about 6 inches, and the average length is about 9 inches. The smallest fish are packed in oil in half-pound square cans and in mustard, tomato sauce and souse in 2-pound oval cans. The fish too large for canning are salted. They are never fat, however, and do not make a high grade of salt fish."

Later in the same report Smith mentioned that Pacific mackerel were used to a small extent for canning and that jack mackerel were "not uncommon" in the San Francisco market.

This first attempt at canning was short-lived. Wilcox (1902, p. 570), discussing conditions in 1899, stated: "With the exception of sardines used for canning, the products of the fisheries were disposed of fresh." Croker (1933, p. 23) said that the canned product described by Smith was not a success and that the plant concentrated on sardines after 1894.

Another publication by Wilcox (1907) gives considerable detail on the "Spanish mackerel"—as distinguished from "chub [now Pacific] mackerel"—fishery of 1904. His data are summarized in Table 2. Of particular interest is the fact that the total catch of 354 tons was greater

TABLE 2

The California Catch of Jack Mackerel for 1904
Data From Wilcox (1907)

County	Pounds landed			
	Seine	Gill and trammel nets	Lines	Totals
Monterey	1,000			1,000
Santa Barbara and Ventura		7,500	3,000	10,500
Los Angeles and Orange	426,300	42,740	46,660	515,700
San Diego		3,436	177,829	181,265
Totals	427,300	53,676	227,489	708,465

than that reported in any year from 1926 (the first year for which there are official state records) through 1932. Further, in only one year (1947) since 1926 has the San Diego catch surpassed the 91 tons landed there in 1904. The 1904 catch of Pacific mackerel was 67 tons. Apparently the entire Los Angeles seine catch was canned, for in Wilcox' discussion of the sardine fishery (which, incidentally, yielded only 161 tons at Los Angeles) he stated (p. 15): "The catch in 1904 was made with purse seines by a gasoline steamer which cruised all the season between San Monico [sic] and Redondo and occasionally as far north as Santa Barbara and off the islands of Santa Catalina and Santa Cruz. Besides the sardines, the steamer took 426,300 pounds of Spanish mackerel, the latter being

used at the cannery to help out the season's pack which amounted to 4,292 cases of sardines and 5,834 cases of other fish."

Records of jack mackerel landings are virtually nonexistent from 1905 until 1926, largely because of the confusion in common names and the lack of scientific names in the reports for those years. Records of the State of California commence in 1916, but through 1925 did not distinguish between Pacific and jack mackerel. During this period the total catch of the two did not exceed 2,500 tons, and probably consisted mostly of Pacifics. In 1926 and 1927, the jack mackerel catch averaged about $8\frac{1}{2}$ percent of the Pacific (Fry, 1930, p. 25), and the catch of jacks alone did not reach even 500 tons until 1933.

Starks (1918, p. 126) discussed the jack mackerel as a commercial variety, saying: "As a food fish it is inferior to the mackerel, being rather coarse fleshed. Little has been done in preserving it." Within a few years, however, estimates of its desirability were to change, for Scofield (1924, p. 87) wrote as follows regarding Pacifics and jacks:

"The other species commonly taken at Monterey is the horse mackerel (*Trachurus symmetricus*), a fish that has been considered very inferior, and in past years was not taken in quantity because there was either no sale for it or the price was so low as to leave little profit in handling it. In the last two or three years there has been an unexpected development in the mackerel fishery. It has been discovered that the people of Latin races and orientals, especially Chinese, living in the state are very fond of the horse mackerel and are willing to pay an advanced price for it, so that now (Feb. 1924) the sale value of the two mackerels has been completely reversed. The choice black or zebra striped mackerel is sold by the fishermen at 4 cents per pound in the round, and the horse mackerel, formerly held in such contempt, is sold at 8 cents."

CATCH TRENDS, 1926-1951

Commencing in 1926, landings of Pacific and jack mackerel were segregated in the catch statistics, which are presented by region and year in Table 3. The Los Angeles region (Los Angeles and Orange Counties) has been dominant throughout the 26-year period, though deliveries in the Monterey and Santa Barbara regions have been substantial in recent years.

From 1926 through 1932 the state-wide catch did not surpass 350 tons. Croker (1929) noted in discussing the catch in 1926 and 1927 that jack mackerel then commanded a higher price than Pacifics and was more in demand in metropolitan markets. (It was not until 1928 that large-scale canning of Pacific mackerel commenced.) Croker (1933, p. 16) stated, with reference to the years prior to 1932, "The horse mackerel is not of very great importance in the fisheries of California, principally because the market for it has not been developed." Later (p. 38), in discussing the Monterey mackerel fishery, he remarked, "The price paid for this species is somewhat higher than the price of Pacific mackerel, so the horse mackerel is not relatively so unimportant as would appear at first glance. Most . . . is used fresh but some is salted and dried." With regard to the Los Angeles fishery he wrote (p. 51):

" . . . the horse mackerel is fifth in importance of the locally caught market fish. . . . Although there is no great demand . . . the fishermen are able to sell all they can catch. The horse mackerel seems to be

TABLE 3

Annual Landings in Tons of Jack Mackerel

Year	Region					Total
	San Francisco	Monterey	Santa Barbara	Los Angeles	San Diego	
1926		28		89		117
1927		28		203		231
1928		14		255		269
1929		19		330		349
1930		48		137		185
1931		124		157		281
1932		60	1	208		269
1933		17	2	187		206
1934		69		720	1	790
1935		73		1,917	1	1,991
1936		15		2,253	31	2,299
1937		21		3,202	49	3,272
1938	-	19	-	1,977	71	2,067
1939	--	41		1,837	1	1,879
1940	---	55	-	656	6	717
1941	----	132	-	901		1,033
1942	--	162		2,484	28	2,674
1943	78	81	-	6,189		6,348
1944	---	41	-	6,347		6,388
1945	---	125	-	1,390		1,515
1946	---	3,579	-	3,966		7,545
1947	--	1,076	6,774	56,550	121	64,521
1948	--	4,444	2,811	29,118	15	36,388
1949	--	2,091	1,113	22,409	13	25,626
1950	440	15,756	1,335	49,076	23	66,630
1951	---	388	2,605	41,906	21	44,920

scarcer than the Pacific mackerel and there is seldom a glut of these fish on the market.

"The horse mackerel commands a higher price than the mackerel, because it does not spoil so readily and is said to have a better flavor and also because it is scarcer and therefore more desirable. . . . The price paid to the fishermen varies from 2 to 6 cents per pound."

And finally (p. 134), "As a sport fish the horse mackerel is unimportant. This species is nowhere as abundant as the Pacific mackerel and is never the subject of special fishing effort. It is taken in small numbers incidental to the capture of mackerel, bonito and other fish of similar habits. The young are often taken by pier fishermen. The horse mackerel is a fine game fish for its size and would undoubtedly be very popular if it were more abundant. Many people would rather catch and eat it than the Pacific mackerel."

Landings increased in 1933 and 1934 and then rose sharply to nearly 5,000 tons in 1935, virtually all of which was delivered in the Los Angeles region. Fry (1937, pp. 22-23) wrote:

"There is no special fishery for horse mackerel, they are caught incidentally by boats fishing for the Pacific mackerel. Most of the horse mackerel taken are mixed with the other species, though it is not at all uncommon for a boat to find an unmixed school. The fish are taken with ring nets and purse seines by boats fishing for the canneries and with set lines by the fresh fish market boats.

"At the fresh fish markets horse mackerel are well regarded and often bring a better price than mackerel. At the canneries this does not hold true. The Pacific mackerel makes a better pack and hence brings a better price. In 1935 the cannery prices for the two species were $15 and $6 per ton, respectively. The result of this peculiar situation is that when a cannery boat brings in a load containing any great quantity of horse mackerel it will often go first to the fresh fish markets and sell what it can. The markets will seldom accept net-caught mackerel, as the rough handling usually bruises them enough so that they will not keep well. Horse mackerel withstand the bruising much better and are perfectly acceptable.

"The rise in the horse mackerel catch in 1933, 1934, and 1935 was due primarily to the heavy mackerel canning which has been going on in the Los Angeles region. In 1935 there was a particularly great rise because for a period of months there was very heavy mackerel fishing going on around the Channel Islands. Horse mackerel are much more abundant in those waters than along the mainland shore, and as a result many more of them were taken by the mackerel boats. . . .

"At Monterey the horse mackerel landings were about normal, even though canning activities brought the Pacific mackerel catch far above normal."

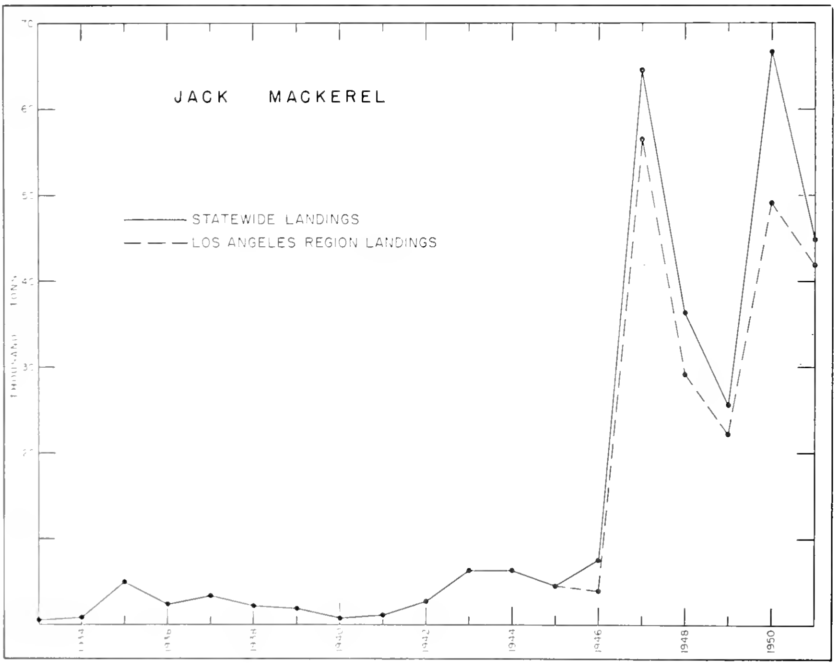

FIGURE 2. Jack mackerel landings, 1933-1951. Virtually the entire catch prior to 1946 was landed in the Los Angeles region. Landings prior to 1933 were less than 500 tons per year. Data from Table 3.

After 1935, landings dropped considerably, falling to a low of 717 tons in 1940. During the next six years, catches were much more substantial, surpassing 6,000 tons in 1943 and 1944, and 7,500 tons in 1946. It was in 1947 that the fishery experienced its tremendous expansion. Landings reached an unbelievable 64,500 tons, of which 56,500 was delivered in the Los Angeles region. It has been of major importance since, with 1950 the peak year with 66,630 tons, about 50,000 of which was delivered in the Los Angeles region. In terms of tons landed, jack mackerel ranked third among the State's fisheries in 1947, 1948, and 1950, and fourth in 1949 and 1951. In terms of dollar return to the fishermen, it came fourth in 1947 and 1949, fifth in 1948 and 1950, and sixth in 1951.

THE LOS ANGELES REGION FISHERY

The supremacy of the Los Angeles region has been seriously challenged but twice in the period 1926-1951. In 1931, a year of no consequence so far as total landings are concerned, the Monterey region reported 124 tons as against Los Angeles' 157. In 1946, the last year of a relatively minor fishery, Monterey handled 3,579 tons compared with Los Angeles' 3,966. Since the expansion of 1947, Los Angeles' share has been from 74 to 93 percent of the annual state-wide catch. The great bulk of the catch is processed at canneries in the Los Angeles-Long Beach Harbor area. In addition, a portion of the tonnage landed in the Santa Barbara region is shipped by truck to these canneries.

Gear

Records of catch by gear are not available for the early years. Croker (1933, p. 51) stated:

"The same boats, fishing in the same places with the same gear, take both mackerel and horse mackerel for the markets. In addition to the hook and line boats, which really fish for mackerel in particular and take horse mackerel only incidentally, some of the ring net boats fishing for miscellaneous market fish deliver occasional fares of horse mackerel. The ring net boats fishing mackerel for the canneries sometimes encounter schools of horse mackerel, make catches and sell the fish to the wholesale markets for a much higher price than any mackerel they might catch would command at the canneries. Horse mackerel are not so easily bruised by a net as the Pacific mackerel and are in any event relatively scarce, so the fresh fish dealers are willing to accept net-caught horse mackerel."

Fry (1937, p. 22) mentioned only net-caught fish in discussing the 1935 catch. Certainly the net boats took most of the fish, and records since 1947 show only a few thousand pounds each year taken by gear other than seines. Most of this is taken accidentally by Pacific mackerel scoop fishermen.

Monthly Landings

Monthly landings for the period 1934 (the first year of more than a nominal catch) through 1951 are presented in Table 4. During the 13 years of a minor fishery, 1934-1946, the total catch was but 39,839 tons—less than was landed in the months of November and December, 1947. November was the best average month during these years, and about 80 percent of all landings came in during the period September-January.

TABLE 4

Monthly Landings in Tons of Jack Mackerel—Los Angeles Region

Month	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952
January	17	70	30	55	1,113	1,284	14	16	15	2,101	172	592	405	1,611	7,011	2,339	501	4,426	2,746
February	45	20	13	491	339	----	7	154	9	196	44	108	388	4,816	4,838	1,513	6,654	2,201	247
March	17	6	3	46	21	61	12	16	47	18	1	----	6	1,327	2,017	1,710	4,081	2,980	1,026
April		15	----	21	----	----	----	----	----	23	----	2	2	709	116	609	2,551	5,120	3,175
May	21	566	102	141	----	----	7	----	----	1	12	5	1	19	14	258	3,679	4,329	2,314
June	19	1,483	129	506	2	12	6	7	3	----	12	9	30	318	1	79	892	3,682	1,304
July	34	62	220	608	30	25	28	104	----	----	7	5	2	164	906	1,341	6,209	2,835	----
August	22	493	291	96	78	7	150	178	----	694	78	1	22	286	2,889	2,297	3,339	4,516	----
September	51	1,456	416	270	125	219	117	68	252	412	2,819	19	540	3,324	5,086	2,400	4,887	4,641	----
October	170	305	503	167	3	2	197	297	715	133	1,062	407	265	2,959	215	7,231	6,494	3,854	----
November	141	193	1	748	57	208	94	48	510	2,466	1,256	1,340	744	19,175	377	1,641	5,803	2,491	----
December	183	248	545	53	209	19	24	13	933	145	884	1,902	1,558	21,812	5,675	691	3,983	828	----
Totals	720	4,917	2,253	3,202	1,977	1,837	656	901	2,484	6,189	6,347	4,390	3,966	56,550	29,148	22,109	49,076	41,906	----

April was the low month. This pattern follows the Pacific mackerel and sardine seasons very closely—landings high in the fall and winter when a maximum number of vessels were on the grounds and minimal in April when the sardine season is closed and the period of scarcity of Pacifics is at its height.

Experience in the following five years, 1947-1951, indicates that lack of fishing rather than lack of fish accounted for the low spring catches. In 1947, 1948 and 1949, many boats remained in the fishery through March and into April. The low month in 1947 was May; in the next two years, June. In 1950 and 1951 monthly landings fluctuated considerably and the high month for 1951 was April. A sizable fleet remained on the grounds throughout both years. There are periods, erratic in their occurrence, when jack mackerel are not to be found, but there is no evidence of a seasonal occurrence similar to that exhibited by the Pacific mackerel. The total catch in 1948 and 1949 was held down by fishermen's strikes in October and November, 1948, and in November and December, 1949.

The Fishing Season

Despite the evidence of 1950 and 1951 that jack mackerel are available throughout the year, the calendar year does not comprise an ideal unit for either catch or biological studies. The fishing fleet is actually seeking three species, primarily sardines, and the maximum number of boats is operating during the sardine season which is limited by law to the period October 1st-February 1st in Southern California. Further, as has been mentioned, Pacific mackerel are scarce in the late winter and spring with the period of scarcity usually most marked in April. The Pacific mackerel season has traditionally been regarded as opening in May and extending through the following April. (For a discussion of the Pacific mackerel fishery during this same period see Roedel, 1952. The rise in summer seiner catches of Pacific mackerel in recent seasons, noted in that paper, is explained in a large degree by the availability and marketability of jack mackerel which made it profitable for the boats to fish.) The number of active boats thus tends to be at a minimum at this time. When investigations of the jack mackerel were undertaken in 1947, the same period was selected as the fishing season, based on landing figures for the previous years and for convenience in comparing catches of the three species. It has since been found that this forms a convenient biological season as well, because completion of a year's growth is indicated in the spring. For these reasons, we continue to regard the jack mackerel fishing season as commencing in May. Seasonal landings appear in Table 5 and Figure 3.

TABLE 5

Seasonal Landings in Tons of Jack Mackerel—Los Angeles Region, 1934-35—1951-52
The Season Extends From May Through April

Season	Tons	Season	Tons	Season	Tons
1934-35	752	1940-41	809	1946-47	11,658
1935-36	4,852	1941-42	786	1947-48	62,042
1936-37	2,820	1942-43	4,751	1948-49	21,334
1937-38	4,062	1943-44	4,068	1949-50	29,728
1938-39	1,849	1944-45	6,832	1950-51	50,016
1939-40	525	1945-46	4,489	1951-52	34,370

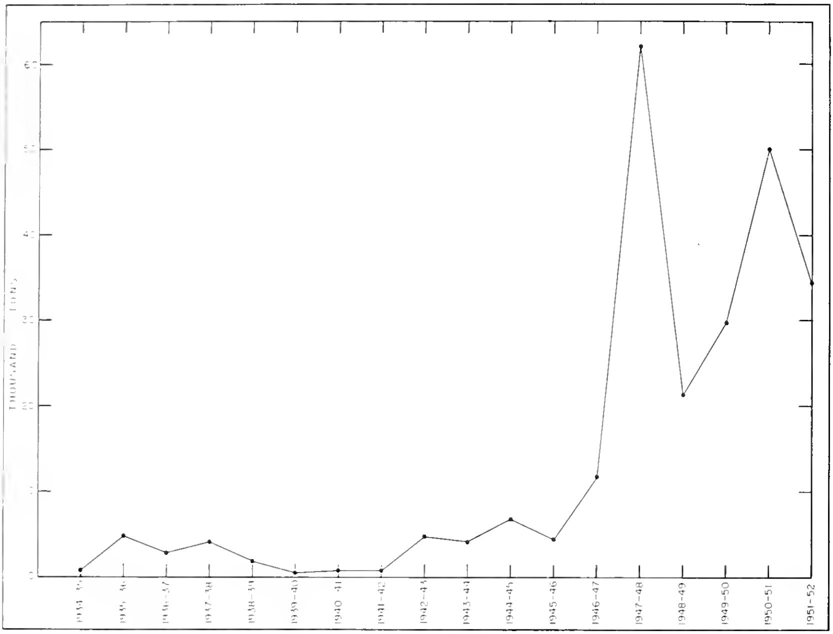

FIGURE 3. Seasonal landings of jack mackerel in the Los Angeles region, 1934-35—1951-52. The season is defined as commencing in May and ending in April. Data from Table 5.

Price

The price paid to the fishermen for jack mackerel was for many years intermediate between that for Pacific mackerel and sardines, with Pacifics commanding the highest figure. Since 1947, prices have fluctuated considerably, and over most of the period jack mackerel brought the same as sardines. In 1935-36 and 1936-37 the price for jack mackerel was the lowest of the three: \$6 per ton, compared with \$8 and \$10 for sardines and \$15 and \$18 for Pacifics. Jacks occupied the intermediate position in the ensuing seasons through 1946-47. The price was \$16 from 1937-38 through 1940-41, \$22.50 in 1941-42, \$35 through 1945-46, and \$45 for the most part in 1946-47. The prevailing price started at \$45 in 1947-48, but rose to \$60 in December. In 1948-49, the price reached \$67.50 in October but dropped to \$50 in November, where it remained. Sardine prices were identical in both seasons. In 1949-50 the jack mackerel price fluctuated considerably: \$50 from June through September, \$25 to \$40 in October, \$32.50 for the next three months, and \$40 thereafter. The sardine price was \$32.50. In 1950-51, the prevailing price started at \$40, fluctuated from \$25 to \$45 during the sardine season and ended at \$45. Sardines brought \$35 for most of the season, the price rising to \$45 at the close. In 1951-52, both jacks and sardines brought \$46 at the start and \$60 later in the season.

Fishing Grounds

In general, the fishing grounds for jack mackerel are the same as those for Pacifics and sardines: the mainland coast from Point Conception to the Mexican boundary and offshore to include the channel islands. For a knowledge about fishing localities, the Department of Fish and Game is dependent largely on information supplied by the fisherman to the weighmaster at the time of unloading. The coastal waters of California are divided into numbered blocks, each encompassing 10 minutes of latitude and 10 minutes of longitude, and the fish receipt made out by the weighmaster contains a space in which to record the number of the block in which the catch was made. This system has been in effect since the early thirties, and now provides, on the average, reasonably accurate (judging from auxiliary information obtained through interviews with fishermen and field observations) and reasonably complete records. In presenting the data which follow, catches by individual blocks have been grouped into general fishing areas as shown in Figure 4. The Santa Monica, Newport and Santa Catalina areas comprise the "local" grounds, the others the "distant."[2]

Prior to 1935, we have no data on jack mackerel fishing grounds, and records are scant for the 1935-36 and 1936-37 seasons. Fry (1937, p. 22) attributed the good fishery of 1935 to "very heavy [Pacific] mackerel fishing . . . around the Channel Islands," but actual locality records are so few as to be meaningless. For the seasons following the data are quite adequate. Catches by general area are presented in Table 6. From 1936-37 through 1942-43, catches on the distant grounds exceeded those on the local, largely because of the contribution of the northern area, where the fishery then, as now, centered at Anacapa and Santa Cruz Islands. Since 1942-43, the total contribution of local areas has been heavier than that of the distant. Fishing has tended to concentrate in the last few seasons at Anacapa Island and the east end of Santa Cruz, off Pt. Vicente, at Santa Catalina Island, particularly the west end, in the Newport Beach-Dana Point area, off Oceanside, and at San Clemente Island. The average catch per numbered block for the five seasons 1947-48—1951-52 is shown in Figure 5. Block number 720, Pt. Vicente, has been by far the most productive with an average seasonal catch of nearly 4800 tons. Block number 762, at the west end of Santa Catalina Island followed with about 2500 tons, and three blocks, numbers 684 (Anacapa Island), 685 (east end of Santa Cruz Island) and 738 (Newport Beach) fell in the 1500- to 2000-ton class.

Some information is available as to the distance from shore at which catches are made. Commencing in 1947, routine samples have been taken from the commercial catch to determine the size and age of the fish. At the time that the sample is taken, the vessel's captain is asked to provide certain information about fishing conditions including the locality of catch. Of 396 samples taken from July, 1947, through April,

[2] In the summer of 1952, the seiners extended their operations into a hitherto virtually unexploited area comprising Tanner and Cortes Banks. These banks lie, respectively, some 30 and 40 miles southeast of San Clemente Island. They are so far from port that in past years they were very rarely fished even though it was known that both jack and Pacific mackerel were to be found on them. However, fishing was so poor on the regular grounds that from mid-July on the fleet worked both banks and enjoyed considerable success throughout the summer. In late September, huge catches of jacks were made on these banks and fishing was still fairly good as this paper goes to press (early November). Preliminary figures for September indicate a catch of about 19,000 tons.

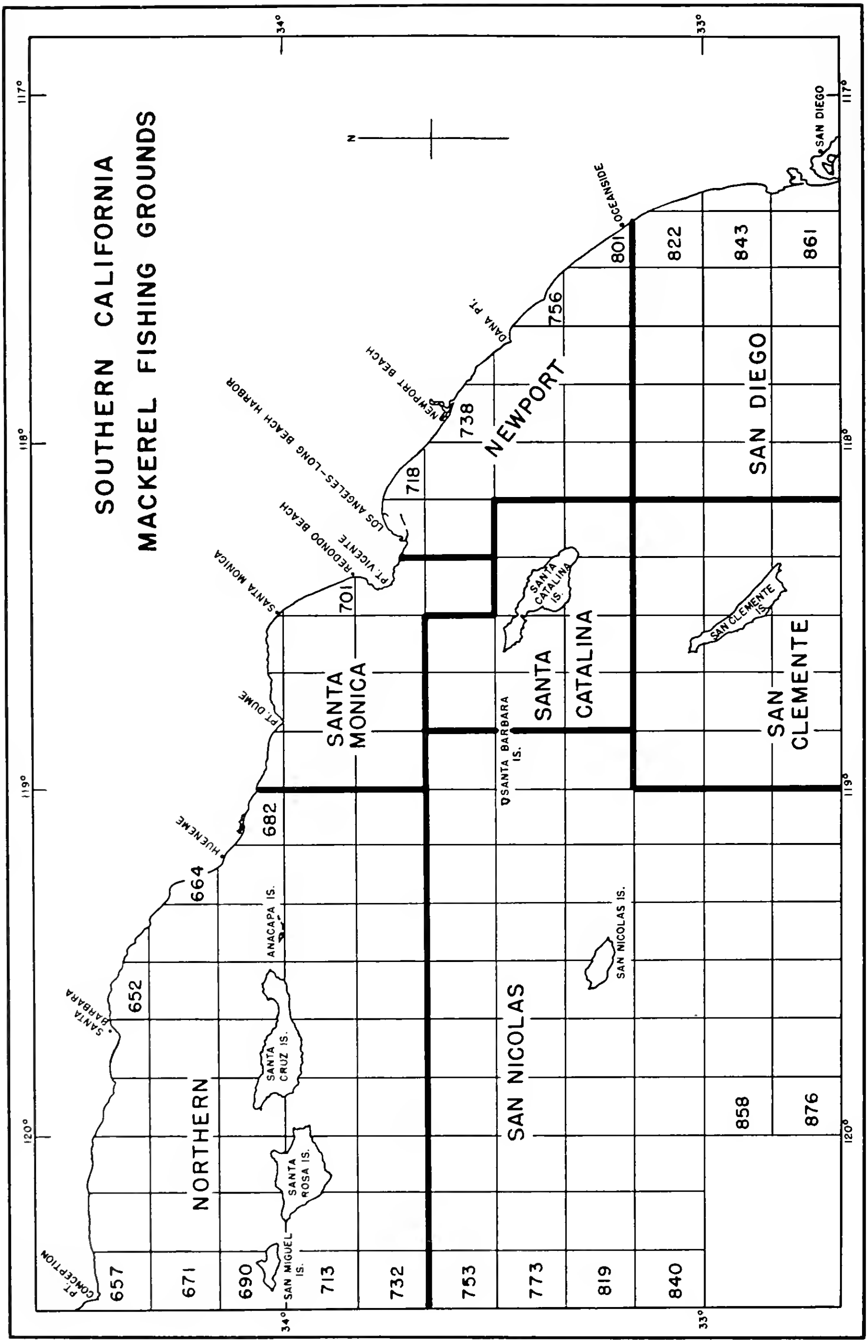

FIGURE 4. The coast of Southern California showing general fishing grounds for both jack and Pacific mackerel and numbered blocks

TABLE 6

Catches in Tons of Jack Mackerel by General Fishing Area. Los Angeles Region Landings, 1935-36—1951-52

Fishing area	1935 -36	1936 -37	1937 -38	1938 -39	1939 -40	1940 -41	1941 -42	1942 -43	1943 -44	1944 -45	1945 -46	1946 -47	1947 -48	1948 -49	1949 -50	1950 -51	1951 -52
Santa Monica	340	82	119	118	25	99	232	1,111	639	1,090	1,334	1,290	8,393	7,353	9,510	13,526	9,157
Newport	31	75	308	30	4	175	68	444	569	805	793	2,753	9,552	3,136	4,818	16,437	11,274
Santa Catalina	8	34	128	391	105	8	13	442	1,175	3,844	976	2,949	14,318	6,242	2,811	1,413	1,303
Total, local	379	191	555	569	134	282	313	1,997	2,383	5,739	3,103	6,992	32,263	16,731	17,139	31,376	21,733
Northern	20	294	1,788	738	244	192	354	2,028	518	274	680	3,615	20,957	5,063	7,852	12,060	8,322
San Nicholas		18	56	196	92	180	54	23	327	8	216	158	767	156	326	1,082	260
San Clemente	109	67	113	51	15	5	1	68	366	43		415	806	351	3,559	1,125	3,054
San Diego						43			73		55	24	4,335	306	283	2,876	86
Total, distant	129	376	2,257	985	351	420	109	2,119	1,284	325	951	4,212	26,868	5,874	12,020	17,144	11,722
Total known origin	508	567	2,812	1,554	485	702	722	4,116	3,667	6,064	4,054	11,204	[illegible]	[illegible]	[illegible]	[illegible]	33,453
Origin unknown	1,344	2,253	1,250	295	40	107	64	635	401	768	135	454	[illegible]	724	[illegible]	[illegible]	417
Season totals	1,852	2,820	4,062	1,849	525	809	786	4,751	4,068	6,832	4,189	11,658	[illegible]	[illegible]	[illegible]	[illegible]	33,870

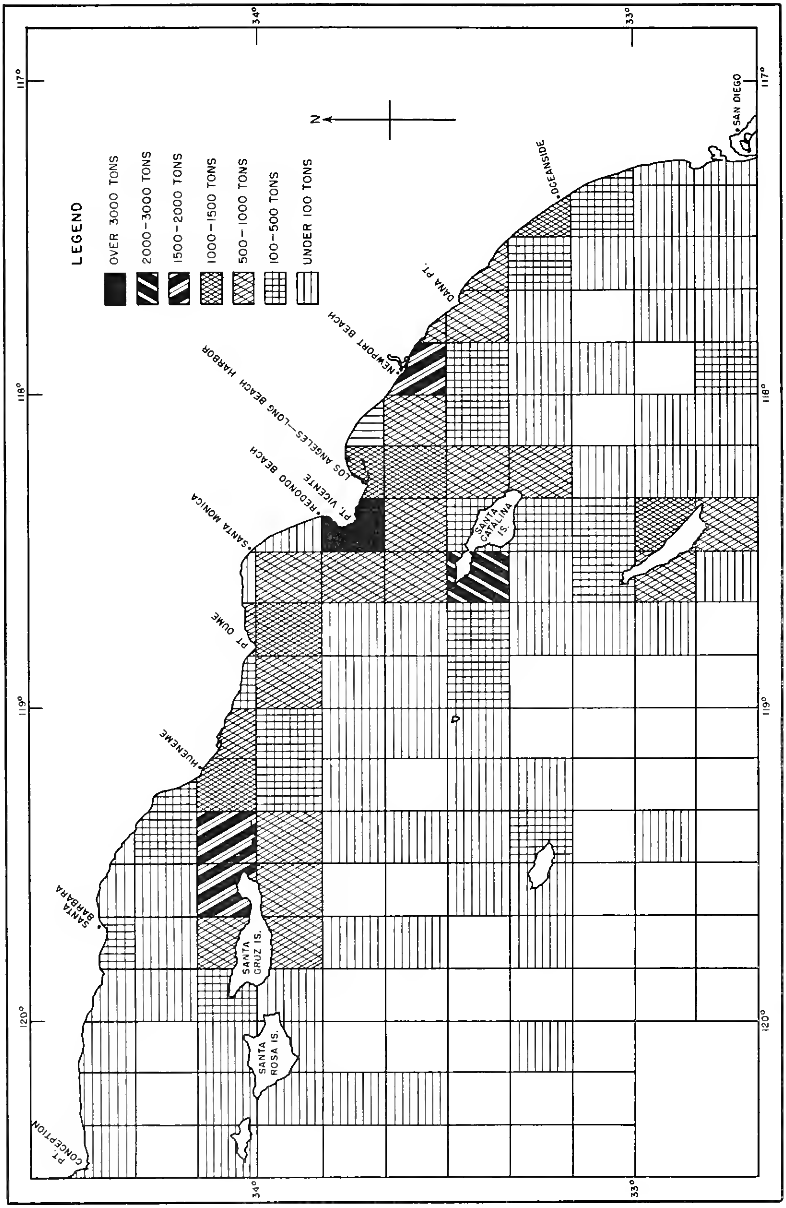

FIGURE 5. Average seasonal catch per numbered black of jack mackerel for the five seasons 1947-48—1951-52

1952, reasonably precise information regarding locality was given for 274 catches (Table 7), almost half of which were made in 1951-52. Judging from these records, about 55 percent of the catches were made less than three miles from the nearest land mass and only 7.7 percent eight

TABLE 7

Jack Mackerel Catch Localities
Distance From Nearest Land as Reported by Fishing Boat Captains
in Personal Interviews, 1947-48 – 1951-52 Seasons

	Distance in miles from land									
	Less than 1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-12	Totals
Mainland, south of Los Angeles Harbor	11	16	19	19	9	11	6	5	16	112
Mainland, north of Los Angeles Harbor	3	17	15	6	3	4	1	0	1	53
Santa Cruz and Anacapa Islands	11	9	4	4	1	1	1	0	0	31
Santa Catalina Island	6	2	5*	8	10	4	3	1	2	41
San Clemente Island	9	7	11	4	0	1	0	0	2	34
Totals	46	51	54	41	23	21	11	6	21	274
Percentages	16.8	18.6	19.7	15.0	8.4	7.7	4.0	2.2	7.7	100.1

* Includes one catch at Santa Barbara Island.

or more miles from land. Most of the waters within three miles of Santa Catalina Island are closed to seining, which accounts for the relatively large number of catches reported three or more miles distant from that island. The catches reported some distance from the mainland south of Los Angeles Harbor were made for the most part between the harbor and Santa Catalina Island.

There is little evidence in the records for 1950 and 1951 to indicate that jack mackerel appear on specific grounds at specific times of the year. These are the only two years in which fishing continued on a fair scale throughout a 12-month period.

In 1950, Anacapa and Santa Cruz Islands and the Pt. Vicente area were the leading producers from January through August. (San Clemente Island led in June, a month of small landings). In 1951, the Newport Beach-Dana Point area was the center of an excellent fishery from March through May, with Pt. Vicente the favored ground in January and February, and Anacapa and Santa Cruz from July through August. From September through December, 1950, records show greatest tonnages caught along the mainland coast from Pt. Dume to Dana Point, with good catches at San Clemente Island in September. In 1951, the Pt. Vicente area led in September, San Clemente Island in October, Anacapa and San Clemente Islands and Pt. Vicente in November, and Anacapa and Santa Catalina Islands in December.

Size of Fish in the Catch

Most of the fish in the commercial catch measured since the sampling program was instituted have ranged from about 8 to about 15 inches in total length (about 185 to about 350 mm. fork length). These sizes are

almost identical with those given by Smith (1895) for fish taken in the initial canning venture of 1893 (see page 49). On rare occasions catches are made which consist entirely of extremely large individuals. The largest specimen so far observed was $26\frac{1}{2}$ inches total length and weighed $4\frac{1}{2}$ pounds.

THE SANTA BARBARA REGION FISHERY

Landings of jack mackerel in this region (Santa Barbara, San Luis Obispo and Ventura counties) were nil until 1947. Since October, 1947, fair amounts have been delivered, particularly at Port Hueneme. Part of the catch is canned locally; the balance is transshipped for processing elsewhere. Monthly landings for the years 1947-1951 appear in Table 8.

TABLE 8

Monthly Landings in Tons of Jack Mackerel—Santa Barbara Region

	1947	1948	1949	1950	1951
January	----------	693	875	86	387
February	----------	876	----------	----------	48
March	----------	----------	----------	----------	124
April	----------	----------	----------	7	108
May	----------	79	----------	41	----------
June	----------	----------	----------	23	515
July	----------	----------	----------	344	577
August	----------	4	15	236	17
September	----------	13	37	83	39
October	214	210	302	129	421
November	2,796	282	96	176	362
December	3,764	684	88	210	7
Totals	6,774	2,841	1,413	1,335	2,605

This is properly considered as an extension of the Los Angeles region fishery. Boats from the same fleet of purse seiners deliver in both regions, and the fishing grounds chiefly exploited by the Santa Barbara vessels are extremely important to the Los Angeles fishery. Almost the entire catch is reported from the northern fishing area, particularly the mainland adjacent to Port Hueneme and Anacapa and Santa Cruz Islands.

Landings were concentrated in the sardine season through January, 1950. Since April, 1950, there has been a small but fairly consistent fishery based at Port Hueneme. The landing figures are deceptive, for large catches are frequently taken direct to Los Angeles Harbor canneries, rather than being unloaded locally.

THE MONTEREY REGION FISHERY

By far the greatest proportion of the present-day Monterey region jack mackerel catch is made in Monterey Bay and delivered to canneries at the bay ports of Monterey and Moss Landing. The fishery predates the earliest records, for as mentioned earlier (page 47), Lockington (1880) found jack mackerel from Monterey in the San Francisco markets when he made his initial survey in 1878.

Until 1946, the fishery was of very minor importance, though landings are recorded for every year since 1926 (Table 3). With the failure of the sardine fishery in Central California, landings of jack mackerel

increased tremendously, as the local canners, who until then confined their operations to sardines exclusively, were forced to accept other varieties. Monthly landings for the period 1946-51 appear in Table 9.

TABLE 9

Monthly Landings in Tons of Jack Mackerel—Monterey Region

	1946	1947	1948	1949	1950	1951
January	8	33	6		1	
February	1	219	8		1	[illegible]
March	9	69	1		12	[illegible]
April	5	5	77	5	21	70
May	1	16	99	1	2	7
June	3	1	5	2	1	1
July	-	15	2	1		0
August	6	30	8	2	7	14
September	163	308	3,351	821	13,673	[illegible]
October	49	270	705	670	2,000	58
November	- - -			283	32	62
December	3,331	80	182	306		119
Totals	3,579	1,076	4,441	2,091	15,756	388

As in Southern California, this is a roundhaul fishery prosecuted by the sardine purse seiners and smaller ringnet and lampara boats. The cannery fishery first became of significance in December, 1946, when, after several months of poor sardine fishing, the boats suddenly found an abundance of jacks within the bay. In the week ending December 21st, nearly 3,100 tons out of the year's total of 3,579 were landed. Most of the catches were reported from the northern half of the bay, although some came from the southern half and a few from north of the bay as far as Pt. Año Nuevo.

Catches were far smaller in 1947, but almost all of the seiner fleet left for Southern California waters within about two months of the opening of the sardine season on August 1st. (The sardine season in this area closes on January 15th and there is usually relatively little seine fishing during the months closed to sardines.) In 1948, 1949 and 1950, there was a sudden upsurge of jack mackerel landings in September. August sardine fishing was fair in all three years. In 1948, jacks appeared on the grounds early in September. By early October sardine fishing had become so poor that the seiners were moving to Southern California and jack mackerel landings fell off—whether from a lack of boats, a lack of fish or both remains uncertain. In 1949, a sizable fleet remained in Central California during the sardine season and took fair quantities of jacks through December. In 1950, because of poor sardine fishing, a large part of the sardine fleet left for the south in the last week of September; most of those remaining left in early October. Jack mackerel fishing, however, was exceptional, with 13,673 tons landed in September and an additional 2,000 in October. Fishermen had reported jack mackerel schools in the bay late in August. In September, all the canneries operating accepted jacks, but individual boat limits of 15 or 20 tons per night probably held down the total catch. The fish were found within the bay at the beginning and at the end of the month. The remainder of the time they were taken north of the bay and for the most part about

ten miles offshore. Early in October, the demand for jacks by the canners decreased. In 1951, there was little seiner fishing in the area, and jack mackerel landings fell off sharply.

There is a hint that jack mackerel are seasonal in the Monterey Bay area. This was mentioned in some of the earlier accounts. Goode (1882), quoting Jordan, stated that jacks reached Monterey in August. Collins (1892) said they were in the bay from July to October. The records for 1948-50 indicate arrival in quantity early in September. There was a good-sized fleet operating each year in August, and, while the processors did not want jack mackerel, the fishermen did not report their presence except in late August, 1950. With the great fluctuations in fishing pressure through the year associated with the sardine season and its success, little beyond the inference can be drawn at present.

BIOLOGICAL KNOWLEDGE

The Department of Fish and Game undertook an investigation of the jack mackerel in early 1947, when it became apparent that this fish was to play other than a very minor role among the fisheries of California. Up to that time, there had been no biological studies of the species; even its range and relationships with allied species on this coast were matters of some uncertainty. Routine sampling of the commercial catch commenced in July, 1947. This phase of the work provides information as to the sizes and ages of fish entering the commercial catch. The otoliths (ear bones) can be used to determine age, and preliminary work shows that jack mackerel may attain an age of over 20 years. Analyses of the size and age composition of the catch, and studies of the relationships of size, age and weight are in progress, concurrent with studies of maturity, fecundity and food habits.

The relationships of the jack mackerel and its close relatives on the Pacific Coast have been studied (Roedel and Fitch, 1952) and it was found that only the one species of jack mackerel exists in this area. Further, there is no evidence to date of any separate populations along the coast. The southernmost limit of its distribution remains unknown but it becomes progressively less abundant in the southern half of Baja California. We have not taken specimens south of San Juanico Bay (Lat. 26° 15′ N.).

A superficially similar fish, the Mexican scad (*Decapterus hypodus*), which is rather abundant off northern Baja California and has been taken at San Clemente Island, could be confused with the jack mackerel. The scad, however, has enlarged scales only along the posterior half of the lateral line whereas the jack mackerel has enlarged scales along its entire length. Further, both dorsal and anal fins in the scad are followed by a detached finlet. The last dorsal and anal rays of the jack mackerel may be finlet-like in structure but are not widely separated from the fins. The jack mackerel has an accessory lateral line (sometimes difficult to see) running along the back close to the first dorsal fin and extending usually to the second dorsal. This accessory line is lacking in the scad. No other fish within the jack mackerel's range is likely to be confused with it. The fish described as a scad, *Decapterus polyaspis*, from the Pacific northwest has proved to be the very large adult jack mackerel.

FIGURE 6. Mexican scad, *Decapterus hypodus*. Photograph by Al Johns for Vernon M. Haden, San Pedro.

It has been found that the fish attains a much greater size than was supposed. The record specimen to date was 26½ inches (67 cm.) in total length. Schools of large fish 16 to 24 inches (40 to 60 cm.) long have been found at considerable distances from shore, well outside the present limits of the fishery. On rare occasions, they have been taken commercially on the current grounds, and they are sometimes caught by sport fishermen.

Data have been and are being obtained regarding the spawning grounds and season incidental to the California Cooperative Sardine Research Program. The first report (Calif. Mar. Res. Comm., 1950, p. 41) states that the spawning season is similar to that of the sardine (February to August), that larvae were found over a large area off California and Baja California, that larvae were very abundant, and that the center of their distribution was at a considerable distance from shore. The second report (1952, p. 38) remarks that the larvae of jack mackerel were more abundant than those of sardines in 1951. A chart shows that jack mackerel larvae were found at most stations occupied from Central California to central Baja California, with the center of abundance about 150 miles off the coast of Southern California and northern Baja California. Larvae were still being taken at the furthest offshore stations some 350-400 miles from land, so the offshore limit of spawning remains uncertain.

Information as to the abundance of jack mackerel off California and Baja California and as to their abundance relative to sardines, Pacific mackerel and anchovies (*Engraulis mordax*) is being obtained in the course of young sardine surveys conducted each year by the Department in conjunction with the cooperative program. Data for 1950 and 1951 (Radovich, 1952, p. 55-57) indicate that jacks were most abundant off Southern California and northern Baja California and that they were more abundant in 1950 than in 1951 except in the southern portion of Baja California. In Central and Southern California and northern Baja California jack mackerel, sardines and anchovies were found in roughly comparable numbers each year; Pacifics were less abundant. Farther south jacks were less abundant in relation to the other species.

Though much remains to be learned of the jack mackerel's life history, the investigations are progressing at a satisfactory rate and should provide most of the basic biological knowledge in the immediate future.

AN ESTIMATE OF THE STATUS OF THE FISHERY

At the present time, the jack mackerel fishery appears to be in a healthy condition. There are serious gaps in our knowledge of the species' biology and there is no measure of fishing effort; given that information the estimate might be less favorable. However, in the lack of it there are several factors which seem favorable enough to justify the more optimistic approach. First the biological range of the species far exceeds the commercial and there is no evidence to indicate that the Central and Southern California fisheries are drawing on limited, localized populations. It remains to be demonstrated that fish from all portions of the range actually do move freely within the range and ultimately contribute to the fishery. This can be shown only by a tagging program, which at present is beyond the scope of the investigations. A second factor is the existence of a reservoir of large, old fish beyond the limits of the present fishery. These fish would presumably not be exploitable by the seiner fleet. The scarcity of schools scattered over a wide area precludes economic roundhaul fishing even under favorable weather conditions. The abundance of larvae is another good sign, though there is as yet, at least, no possible estimate of survival. Finally, an economic factor operating in favor of the jack mackerel is its relative undesirability compared to the sardine and the Pacific mackerel. When either or both of these species are available, the seiners will take them in preference. It is, of course, the very lack of sardines and Pacifics which has created the market for jacks. Parenthetically, it is the fact that the jack mackerel ranks third which renders any measure of conventional return-per-unit-of-effort virtually unobtainable.

A great deal of additional information must be obtained before any estimates other than more or less educated guesses can be made as to the true condition of the fishery. The program now being carried out should provide much of what is required. Data on general oceanographic conditions now being accumulated through the Cooperative Sardine Research Program will be of great value. The inclusion of the jack mackerel in that broad study effective July 1, 1952, at which time the special research tax was imposed on jack mackerel in addition to sardines, will permit greater emphasis on the areas particularly important to the species and should assist materially in the gathering and analyzing of biological data, particularly with respect to spawning and the behavior of young fish.

It is fortunate that much of the basic knowledge is being obtained while the fishery is relatively young and the population in no apparent straits. Although the evidence of the future may bear out the favorable estimate of today, it is well to be armed against less pleasant possibilities. It is hoped that sufficient data can be obtained in time to foresee, if not forestall, any potential danger to the fishery.

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ELEOTRIS PICTA ADDED TO THE FISH FAUNA OF CALIFORNIA[1]

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Among the numerous recent additions to the list of California fishes the latest, at the time of writing, is that of the spotted sleeper, *Eleotris picta* Kner and Steindachner. This large gobioid fish has been reported as occurring in coastwise waters, chiefly in the lower parts of rivers, from the regions of Cape San Lucas and Mazatlán in México through Central America to Ecuador (Figure 1).

On April 16, 1952, Clifford Fox of Inglewood, California, caught a specimen (Figure 2) of this species at the canal spillway between Winterhaven and the Colorado River, in Imperial County. Using shrimp for bait, he was fishing about midday on the bottom, at a depth of about four feet, for channel catfish. He reports that the strange fish struck the bait and pulled like a catfish.

The specimen was sent to the author for identification by Arthur F. Halloran, Manager of the Imperial National Wildlife Refuge. It proved to be a non-breeding adult male 11¼ inches in total length (228 mm. in standard length). It has been deposited in the fish collection of the California Academy of Sciences in San Francisco (Catalog No. 20582).

Mr. Halloran wrote that, so far as could be determined, no fish of this sort had ever been seen in the region. It is highly probable, indeed, that it was a stray from the Gulf of California or from the scarcely collected tidal reaches of the Colorado River. The specimen may have moved directly from the river, a distance of about one-half mile to the spillway, or it may have come from the river through the canal that was overflowing here.

The specimen was confidently identified as *Eleotris picta* because of its close correspondence with the published descriptions and comparisons of that species referred to in the following synonymy, which I have tried to make complete:

Eleotris picta.—Kner and Steindachner, in Kner, 1863, p. 223-224 (original diagnosis; questioned as new; "Rio Bayano, Südseite von Panama"). Kner and Steindachner, 1865, pl. 3, fig. 1 (name spelled *pictus* in text). Wagner, 1865, p. 90 (Pacific slope of Panamá). Günther, 1868, p. 389, 441 (Pacific side of Isthmus). Regan, 1906, p. 6-8 (comparisons; diagnosis; Pacific coasts and rivers from California to Ecuador; "Cape St. Lucas"; Mazatlán; Presidio; Colima; Río Bayano, Panamá; Ecuador). Starks, 1906, p. 762, 799 (coloration; Guayaquil, Ecuador; Panamá; Gulf of California; Lower California). Eigenmann, 1910, p. 480 ("Pacific slope, Sonora to Ecuador"). Regan, 1913, p. 472 (Río San Juan, Colombia). Meek, 1914, p. 131 (Pacific coast rivers from California to Ecuador; Río Grande at Orotina, and Jesús María, Costa Rica). Meek and Hildebrand, 1916, p. 356-359 (synonymy; comparisons; description; food; West

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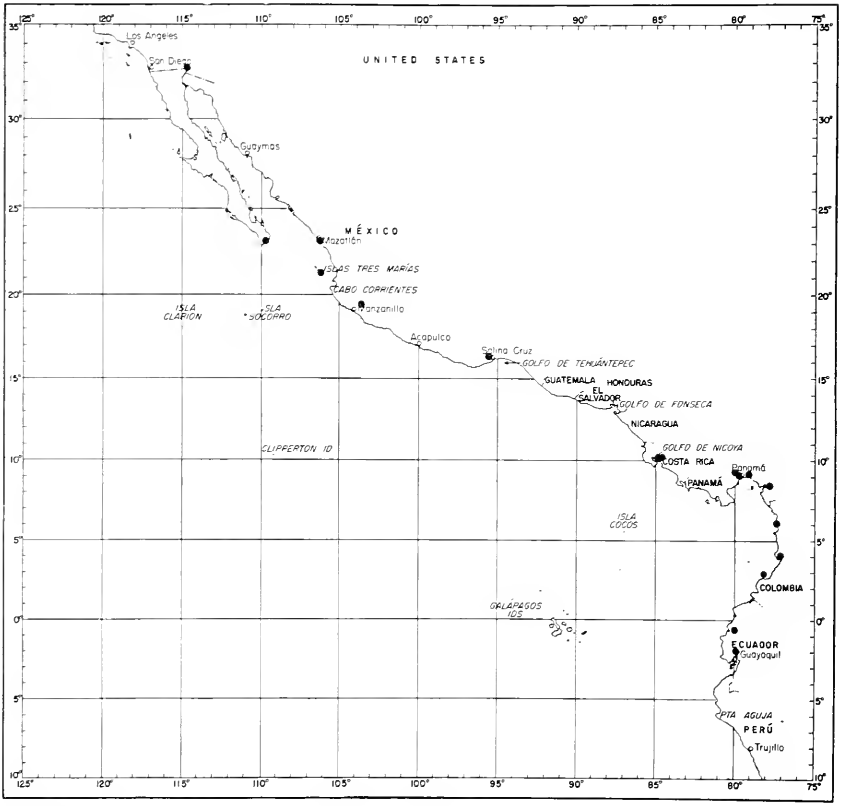

FIGURE 1. Map of the west coast of the Americas showing by stations the distribution of *Eleotris picta*.

The records have all been published (see synonymy) with the exception of one for Río Tehuántepec and two for Colombia (p. 72) and the one for California. The definite records from Panamá are entered, but the species "has been taken in virtually all the streams sampled in the Pacific slope of Panama" (Hildebrand, 1938, p. 347). Base map drawn by Robert W. Kirk.

From north to south the records are as follows: (1) canal spillway, Imperial County, California; (2) Río San José del Cabo, near Cape San Lucas, Baja California; (3) Río Presidio, near Mazatlán, México; (4) Cleopha Island, Tres Marías group; (5) Colima, México; (6) Río Tehuántepec, México; (7) Jesús María, Costa Rica; (8) Río Grande at Orotina, Costa Rica; (9) Panamá Canal, including Miraflores; (10) Río Bayano, Panamá; (11) Río Chucunaque, Panamá; (12) Río San Juan, Colombia; (13) Puerta Utrio, Colombia; (14) Gorgona Island, Colombia; (15) Chone, Ecuador; (16) Guayaquil, Ecuador.

FIGURE 2. First specimen of the spotted sleeper, *Eleotris picta* (family Eleotridae) to be reported from California. Caught in a canal spillway, Imperial County.

Coast and streams, from California to Panama and Ecuador; lowland streams of the Pacific coast of Panamá eastward to Río Bayano). Eigenmann, 1922, p. 210 (references; Pacific coastal streams from Lower California to Ecuador; Guayaquil market and Chone, Ecuador). Breder, 1927, p. 112, 114, 117, 119, 166 (records and distribution in Río Chucunaque drainage of Río Tuyra system, eastern Panamá; food; comparisons). Hubbs, 1932, p. 68-69 (fresh water, Colima, México). Hildebrand, 1938, p. 344-349 (size, character of young, compared with *E. pisonis*; some specimens, probably hybrid, combine characters of the two species, presumably as result of intermixture in Panamá Canal; variant with vomerine teeth; anal flap; food; food value; Lower California to Ecuador; in virtually all streams sampled in Pacific slope of Panamá); 1939, p. 20, 29 (hybridization in locks on Pacific side of Panama Canal, due to contact with *E. pisonis* passing through canal).

Eleotris pictus.—Kner and Steindachner, 1865, p. 18-21 (description [usually quoted, wrongly, as the original]; indicated as "n. Sp. ?"; "Neu Granada [properly "der Isthmusstatt Panama," according to Wagner, 1865, p. 90, footnote 1] und aus dem Rio Bayano"; name spelled *picta* on plate). Günther, 1868, p. 381 (listed). Rutter, 1896, p. 265 (characters; *E. aequidens* as synonym; fresh waters at San Jose del Cabo, Baja California; Panamá). Jordan and Evermann, 1898, p. 2199-2203 (comparisons; description; synonymy; "streams of the Pacific Coast, from Sonora, south to Panama; abundant in Rio Presidio, at Mazatlan . . . , not rare about Panama"). Gilbert and Starks, 1904, p. 169-170, 216 (characters; comparisons; ponds and ditches at Miraflores, Panamá; Gulf of California). Meek, 1904, p. xxxviii, xxxix, lii, 228-229 (synonymy; comparison; description copied; streams of Pacific coast from Sonora to Panamá; Río Presidio at Presidio, México, and Río San José at San José del Cabo, Baja California). Evermann, 1908, p. 30 (San José del Cabo; references). Eigenmann, 1909, p. 299 (Río Presidio at Mazatlán). Ulrey, 1929, p. 10 (Cape San Lucas). Jordan, Evermann, and Clark, 1930, p. 137 (synonymy; "streams about the Gulf of California, from Sonora south to Panama; Rio Presidio, Mazatlan"). Cuesta Terrón, 1932, p. 80 (Cabo San Lucas). Beltrán, 1934, p. 6 (generic name misspelled *Leotris*; "ríos del Golfo de California, de Sonora hacia el Sur"). de Buen, 1940, p. 61 ("Rio Presidio, cerca Mazatlan. . . . Aguas dulces en San José del Cabo, Baja California. . . ."). Brock, 1943, p. 130 (Sonora to Panamá; fresh water, Cleopha Island, Tres Marías group, at Lat. 21° 17′ N., Long. 106° 15′ W.). Fowler, 1944, p. 516 (Guayaquil and Chone, Ecuador; Panamá; Mazatlán and San José del Cabo, México). de Buen, 1947a, p. 290 ("En Baja California (aguas dulces de San José del Cabo.) Río Presidio"); 1947b, p. 329 ("Cuenca del río Presidio"). Alvarez, 1950, p. 133 (characters in key, compared with *E. pisonis*; name misprinted *pinctus*; "Costa del Pacífico en América, desde Baja California a Centroamérica. Entra en los ríos").

Culius aequidens.—Jordan and Gilbert, 1882a, p. 461-462 (original description; near Mazatlán, said to be from fresh water at Presidio); 1882c, p. 372 (Colima, México); 1882d, p. 380 (fresh water near San José, near Cape San Lucas).

Eleotris aequidens.—Eigenmann and Fordice, 1885, p. 75-76, 79-80 (comparisons; synonymy; streams about Gulf of California, south to Colima; said to be abundant in streams of Sinaloa and Lower California). Jordan, 1885a, p. 803 (tropical Pacific Coast; fresh waters of western México and Lower California); 1885c, p. 386 (Colima; Cape San Lucas). Jordan and Eigenmann, 1886, p. 483 (streams about Gulf of California, south to Colima). Eigenmann and Eigenmann, 1888, p. 55 (comparisons; Panamá). Jordan, 1889, p. 333 (Río Presidio, near Mazatlán). Eigenmann, 1893, p. 60 (fresh water at Mazatlán and Colima). Jordan, 1895, p. 493 (color, etc.; rather scarce in Río Presidio; a few from brackish waters or muddy places about the estuary).

Philypnus lateralis (misidentification, in part—see p. 72).—Jordan and Gilbert, 1882b, p. 368 (in part; Cape San Lucas).

Eleotris pisonis (misidentifications).—Eigenmann and Fordice, 1885, p. 75-76, 79-80 (in part; *E. picta* regarded as a synonym; range, in part; Río Bayano, Panamá). Jordan, 1885b, p. 386 (*E. picta* as a synonym; Río Bayano). Jordan and Eigenmann, 1886, p. 483 (*E. picta* as a synonym; range, in part; Río Bayano,

Panamá). Eigenmann and Eigenmann, 1891, p. 71 (in part; Río Bayano; *E. pictus* as a synonym). Eigenmann, 1893, p. 60 (Río Bayano [with erroneous citation]).

The published records for the spotted sleeper, duly noted in the synonymy above, and plotted on the accompanying chart (Figure 1), extend northward only to Río Presidio near Mazatlán, Sinaloa, México, near the lower end of the Gulf of California, and to Río San José, near the tip of Baja California. Both localities lie just within the Tropic of Cancer. The specimen from California was taken approximately 750 miles north of the Río San José record and about 860 miles north of the Río Presidio mouth, and, therefore, constitutes a notable extension of known range.

Among unpublished material I can locate no specimens from intervening locations. In the United States National Museum Leonard P. Schultz and Robert Kanazawa locate only four series, with definite data, from north of Panamá: Nos. 2492, Cape San Lucas, John Xantus (two of the specimens reported by Jordan and Gilbert, 1882b, p. 368, as *Philypnus lateralis*); 30943, near San José, L. Belding (reported as *Culius aequidens* by Jordan and Gilbert, 1882d, p. 380); 37142, Río Presidio, Sinaloa, A. Forrer (reported as *E. aequidens* by Jordan, 1889, p. 333); and 102265, Río Tehuántepec, T. MacDougall, 1936. In the Natural History Museum of Stanford University there are, James Böhlke informs me, five series: Nos. 2907, Mazatlán, Sinaloa, México, D. S. Jordan on Hopkins Expedition (reported by Jordan, 1895, p. 493); 6869, Panamá, C. H. Gilbert and party, January 10 to February 24, 1896 (Gilbert and Starks, 1904, p. 169); 8130, San José del Cabo, Baja California, Gustav Eisen (Rutter, 1896, p. 265); 37538, Puerto Utria, Colombia, in stream on mainland opposite tip of peninsula, G. S. Myers on Hancock Expedition, February 25, 1938; 37539, Watering Bay, Gorgona Island, Colombia, in freshwater stream, G. S. Myers, February 24, 1938. In the Museum of Zoology of the University of Michigan, Robert R. Miller finds no cataloged specimens and states that the species is not included in the numerous recent collections made between Mazatlán and the Colorado River by the late Ralph G. Miller. Nor have Boyd W. Walker and his students at the University of California (Los Angeles) secured any in their recent collecting along the shores of the same region. It was not obtained on the recorded collecting expeditions and surveys in the lower Colorado River (Gilbert and Scofield, 1898; Snyder, 1915; Dill, 1944), or on a collecting trip by Hubbs, Miller, and party in March, 1950, along the river from Imperial Dam in California to below the head of tidewater in Baja California.

The published reports from "Lower California" and "Cape San Lucas" obviously refer to the records of *Culius aequidens* from near San José collected by Belding, and of *Eleotris pictus* from fresh waters at San José del Cabo, collected by Eisen (see synonymy). These fish were doubtless taken in Río San José near its mouth, where it flows through the village of San José del Cabo, some miles distant from Cabo San Lucas. This is a perennial stream, with many gobies and other fishes of marine affinities.

Several authors (Jordan and Evermann, 1898, p. 2202; Eigenmann, 1910, p. 480; Meek, 1904 p. 229; Beltrán, 1934, p. 6; and Brock, 1943, p. 130) have indicated that *E. picta* ranges north to Sonora, but I find

no basis in previous literature for this extension of the range and presume that "Sonora" was entered for "Sinaloa." Three authorities went farther in stating that the range extends north to California, but I assume that these authors (Regan, 1906, p. 8; Meek, 1914, p. 131; and Meek and Hildebrand, 1916, p. 358) miswrote "California" in place of "Baja California" or "Gulf of California."

This northward extension of the recognized range of *Eleotris picta* adds a genus and a family (Eleotridae) to the California list and adds a species to the known fauna of the United States. The range of the genus and family is thus carried up the West Coast about as far as the genus reaches along the Atlantic Coast. *E. pisonis*, the Atlantic analog of *E. picta*, ranges northward to Texas, Florida, and Georgia and another species, variously identified as *E. abacurus* Jordan and Gilbert or as *E. amblyopsis* (Cope), has been reported from South Carolina, at about the same latitude as Imperial County, California (Jordan, Evermann, and Clark, 1930, p. 437, and Fowler, 1945b, p. 218).

Two other large sleepers (eleotrids), *Gobiomorus maculatus* (Günther) and *Dormitator latifrons* (Richardson), which are commonly associated with *Eleotris picta*, might also stray up the Colorado River into California. Neither, however, has yet been found as far north as the Colorado Delta.

The only gobioid fish that has been reported previously from the lower Colorado River is *Gillichthys detrusus*, which Gilbert and Scofield described from "Horseshoe Bend, near the mouth of the Colorado River, in Mexico," and which we seined in tidal fresh water at the Ponga ferry crossing, due east of a point 8.5 miles south of El Mayor, Baja California (our specimens are all small and heavily parasitized). Incidentally, I have now checked all available specimens of *Gillichthys* from Salton Sea and regard all as referable to the California species, *G. mirabilis* Cooper (see discussion by Miller, 1952, p. 39-40). *G. mirabilis*, the mudsucker, has recently been shown by Willis A. Evans and Philip A. Douglas to be well established in Salton Sea.

The published literature indicates that *Eleotris* is relatively uniform along the margin of the Pacific Coast, not breaking up into species as the genus does along the Atlantic Coast. Two reports (Fowler, 1944b, p. 246, and 1945a, p. 135), however, appear to represent a distinct species, from the Upper Río Jurubidá at Nuquí, in the Province of Chocó, northwestern Colombia, at an elevation of about 3,000 feet. It seems to be characterized by the small number of scales (in only 51 rows along the axis, according to Fowler).

Doubts that now seem resolved have been raised regarding both the pertinence and the gender of the name *Eleotris*. The name has been added to the Official List of generic names, with fixed application to the gobioids of the *E. pisonis* sort. That the name should be regarded as feminine seems clear. It was so treated by the original describers (Bloch and Schneider), and by most subsequent authors, including Cuvier, Bleeker, and Günther. According to current discussions names not occurring in Greek or Latin, with terminations like *-is* that are normal to the third declension, take the gender normal to such words. Such words were either masculine or feminine in classical Latin. The original feminine usage would therefore seem acceptable and is here adopted.

The following color notes were made on the specimen, when fresh, by Arthur F. Halloran and his assistant, Gerald E. Duncan: "Dark brown on dorsal surface. Yellowish-brown on sides mixed with small yellow spots. Light gray to white, mixed with yellow in spots, on ventral surface forward of anal fin. Dorsal fins dark, with yellow spots. Caudal fin reddish-brown with light streaks on the end. Other fins reddish with dark spots." As shown in Figure 2 the lower anterior parts are conspicuously light-spotted.

The spotted sleeper can hardly be regarded as a desirable intrusion into the California fauna and it is hoped that it will not follow the striped mullet (*Mugil cephalus*) and the Pacific ten-pounder (*Elops affinis*) in dispersal from the Colorado River into Salton Sea. It has a low rating as a food or game fish, as Hildebrand (1938, p. 346-347) noted in Panamá. Furthermore, its large, well-toothed mouth, with projecting lower jaw, suggests predatory habits. Several authors (see annotated synonymy) have found that the species eats fish.

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THE VENOM OF *UROBATIS HALLERI* (COOPER), THE ROUND STINGRAY[1]

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The literature dealing with stingray venom appears to be the product of a single worker, Vellard (1931, 1932), and deals with the South American freshwater stingray, *Paratrygon motoro* (Müller and Henle).[2] Vellard obtained crude extracts by scraping the ventrolateral glandular grooves of the sting with a scalpel and triturating the material in both distilled water and physiological saline solution. Tests were made with crude extracts and by stabbing the animals with intact stings. The venom was tested on dogs, rabbits, mice, pigeons, reptiles and batrachians. Boiling, strong acids and alcohol were said to destroy the action of the venom. Solutions of the venom stored at 5 degrees C. were reported to lose their potency within a few days.

The present report concerns one of a series of investigations which deal with the venom apparatus of stingrays. The purpose of this particular study was to attempt to determine more exactly the site of venom production in the caudal appendage of *Urobatis halleri* (Cooper) (Fig. 1), the round stingray. *Urobatis halleri* is a common inhabitant of the

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[2] The two species *Taeniura dumerili* and *T. mulleri* as mentioned by Vellard (*ibid.*) are now considered synonymous with *Paratrygon motoro* (Muller and Henle) according to Garman (1913) and Fowler (1948).

FIGURE 1. *Urobatis halleri* (Cooper), the round stingray

shallow bays and sloughs of Southern California and the causative agent for numerous stingray attacks each year.

SPECIMENS USED

One series of 125 specimens of *Urobatis halleri* averaging 25 cm. in total length was obtained by seine from the lagoon shore opposite Seal Beach, California. A second series of 12 specimens of the same species was similarly obtained from Mission Bay, San Diego. All specimens were iced at the time of collection.

METHODS

Sixty of the first series of 125 specimens were placed on ice for 42 hours prior to preparation of extracts; the remaining 65 were frozen three hours after collection and maintained at —7 degrees C. for 40 hours pending extraction. Extracts from the second series were prepared within 18 hours after collection.

Material for extracts was obtained by scraping or sharp dissection from the following regions of the caudal appendage: (1) integumentary tissue from ventrolateral-glandular grooves of the spine; (2) cuneiform area (Halstead and Modglin, 1950); (3) caudal integument from other than the cuneiform area; and (4) slime associated with the sting. Material of these separate fractions was pooled and weighed. Table 1 lists the yields. The aggregate samples were then macerated by mortar and pestle and transferred to graduated cylinders. Sufficient distilled water was

TABLE 1

Extract Yields From Various Caudal Portions of U. halleri

Source	Total weight (grams)	Average amount per specimen (mg.)
60 specimens, iced 42 hours:		
Glandular tissue	0.9	15
Cuneiform tissue	0.55	9
Caudal integument	0.54	9
Slime	0.83	14
65 specimens, iced 12 hours, then frozen 30 hours:		
Glandular tissue	0.58	9
Cuneiform tissue	0.41	6.8
Slime	0.83	13
10 specimens, iced 12 hours:		
Glandular tissue	0.21	21
Cuneiform tissue	0.11	11

added to make 1 ml. of stock extract contain material from 10 average original specimens. Resulting solutions were centrifuged at 2,000 r.p.m. for 15 minutes. The slightly translucent supernatant stock extracts were then decanted. Dilutions of 1:5 of the stock extracts were also prepared with distilled water. Then 1 ml. portions of stock extracts and their 1:5 dilutions were injected intraperitoneally into white mice (strain CC_1) weighing from 19 to 23 gm. each.

RESULTS

Almost invariably mice exhibit a combination of responses which may be termed an "intraperitoneal injection syndrome," which should be distinguished from the toxic symptoms resulting from the injection of venom. The injection syndrome may be observed when 1 ml of distilled water or 0.9 percent saline is used. Immediately following the injection, respiration rate and, usually, depth are increased, and the animal remains normally crouched for a few moments. This is followed by alternate stretching of the hind legs and restlessness. In some mice there is an opisthotonoid arching of the back lasting less than one minute and which may be concomitant with any other responses.

Toxic symptoms appear to consist initially of markedly increased abdominal breathing and motor hyperactivity which at first seems an exaggeration of purposeful movements, but later reflects an apparent inhibition of self-control. Motor ataxia follows and the mouse may exhibit running motions for a few moments while lying incapacitated on its side. Dyspnea becomes marked and paradoxical breathing is often seen with ultimately complete paralysis of the intercostal muscles. The tail and ears exhibit varying degrees of cyanosis. Violent convulsions soon begin and within seconds a marked clonus of the extremities is observed. Reflexes appear to be hyperactive. The agonal period is approximately 10 seconds. Complete respiratory arrest occurs just before all motions cease. In isolated instances somatic muscles may remain in rigid maximum contraction but there is usually a post-mortem relaxation until rigor mortis ensues. All mice were autopsied to eliminate the possibility of death from needle trauma.

Examination of Table 2 reveals that there is considerable variation in individual response to the extracts. It is not possible at this time to demark a quantitative basis of action of the extracts.

Inactivation of the toxin, probably by autolysis, is inhibited but not prevented by temperatures as low as −7 degrees C. and is complete in about 72 hours.

SUMMARY

The venom of the round stingray, *Urobatis halleri*, elicits definite toxic effects following intraperitoneal injection into white mice. The toxic principle is concentrated in the epithelium lining the ventrolateral-glandular grooves of the sting. Integument taken from the caudal appendage was found to be nontoxic. Only one sample from the cuneiform area proved to be toxic and should be regarded as of questionable significance. This toxic substance acts as a convulsant capable of causing death in mice by respiratory arrest.

ACKNOWLEDGMENT

We are grateful for the kind cooperation in the procurement of stingrays which was rendered by Mr. Fred Hagerman and Mr. Jack Schott, California Department of Fish and Game, Terminal Island, and Mr. Fred J. Schwankovsky, First Aid and Water Safety Service, Long Beach Chapter, American Red Cross, Long Beach, California.

TABLE 2

Toxic Manifestations From Intraperitoneal Injections of Various Tissue Extracts of U. halleri Into White Mice

Extract source and titer	Mouse no.	Severity/time in minutes of post-injection appearance of symptoms: Inject. synd.	Back arching	Dyspnea	Motor hyper-activity	Ataxia and tremors	Convul-sions	Death time (min.)	Remarks
Iced 42 hours (1 ml. equals material from 10 specimens):									
Glandular tissue	1	+++		+++ 12	—	++++24	+++ 25	—	The only death from cuneiform area extract.
Cuneiform tissue	2	+++		±	—	—	+++ 55	63	
Caudal integument	3	++		—	—	—	—	—	
Slime	4	++	—	—	—	—	—	—	
Iced 42 hours (1 ml. equals material from 2 specimens):									
Glandular tissue	1	+++	++++ 2	+ 5		—	±	72	Dyspnea alternating with deep respiratory excursion.
	2	++		—		—	+ 90	93	
	3	++		—	+++ 26	—	—	76	
	4	+++		++++ 15	+++ 2	++++ 3	—	17	Immediate post-mortem rigor mortis.
Cuneiform tissue	1	++	—	—	—	—	—	—	
	2	++	—	—	—	—	—	—	
	3	++	—	—	—	—	—	—	
	4	++	—	—	—	—	—	—	
Caudal integument	1	++	—	—	—	—	—	—	
	2	++	—	—	—	—	—	—	
	3	++	—	—	—	—	—	—	
	4	++	—	—	—	—	—	—	
Slime	1	++	—	—	—	—	—	—	Unusual motor hypoactivity.
	2	++	—	—	—	—	—	—	
	3	++	—	—	—	—	—	—	
	4	++		—	—	—	—	—	
Iced 12 hours, then frozen 30 hours (1 ml. equals 10 specimens):									
Glandular tissue	1	+++	—	±	++++190	—	—	—	Extremely restless.
Cuneiform tissue	2	++		—	—	—	—	—	

Iced 12 hours, then frozen 30 hours (1 ml. equals 2 specimens):									
Glandular tissue	1	++	—	—	—		—	—	
	2	++	—	—	—	—	—	—	
	3	++	—	—	—	—	—	—	
	4	++	—			—	—		
Cuneiform tissue	1	++	—	—	—	—	—	—	
	2	++				—	—	—	
	3	++					—	—	
	4	++		—		—	—	—	
Iced 12 hours (1 ml. equals 10 specimens):									
Glandular tissue	1	+++		++ 2	++ 1	++++ 14	+++++ 15½	16	Transient splaying 3 minutes before death.
Cuneiform tissue	2	++		±	—	—	—		
Iced 12 hours (1 ml. equals 2 specimens):									
Glandular tissue	1	++		+++ 3	—	+ 30	++ 32	36	No agonal convulsion.
	2	+++		6	—		++++ 11	28	Violent agonal convulsion.
	3	++		+ 16				30	
	4	++		+ 34		36	++++ 40	48	Prolonged [illegible]
Cuneiform tissue	1	++							
	2	++							
	3	++							
	4	++							

LEGEND. Glandular tissue: Portion of the integumentary sheath scraped from the ventrolateral glandular grooves of the sting.
Cuneiform tissue: Tissue removed from the thickened wedge-shaped portion of the integument on the dorsum of the caudal appendage [illegible] the sting.
Caudal integument: Integument removed from the caudal appendage from a region other than the cuneiform area.
+ Indicates a positive reaction was obtained.
— Indicates no reaction was obtained.

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PRODUCTION OF THE CANADA GOOSE ON HONEY LAKE REFUGE, LASSEN COUNTY, CALIFORNIA[1]

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INTRODUCTION

The Great Basin Canada goose (*Branta canadensis moffitti*) as listed by Musgrove (1947) is known by many different names. Some of the more common local names are honker, Canada honker, wild goose, black necked goose and brant (Kortright, 1943). Of the many species of geese in California this is the only one that remains in the spring to nest, and then only in the northeastern part of the State. Honey Lake Valley is one of the most productive areas for Canada geese in California. Other areas with high production are Tule Lake and Lower Klamath National Wildlife Refuges and Goose Lake. Another center utilized by the Canada goose is found along the Pit River in Modoc County.

There has been a lack of recent information on the waterfowl of the Great Basin area of California. Moffitt, (1931) made a study on the status of the Canada goose in California and Dow (1943) completed a two-year nesting study in the Honey Lake Valley. Part of the area used by Dow included the present study area; therefore, several comparisons will be made to his paper.

The spring migrants arrive in Honey Lake Valley in late February and early March. During mild winters many of the geese remain in the valley as residents. They begin to establish territories and their nesting starts by the first week in March. Bent (1925) states that the older geese are mated for life and many of the younger birds, pairing for the first time, court and select mates while still on the wintering ground or just before spring migration. This possibly explains the absence of courtship of the breeding geese on the Honey Lake Refuge during this study.

LOCALE OF THE STUDY

Northeastern California, the only part of the state where the Canada goose nests in any number, has many reservoirs, swamps and marshes which provide ideal nesting conditions in the spring. Moffitt (1931) states that Canada geese breed commonly throughout the elevated lakes of Lassen and Modoc Counties, in the vicinity of Lake Almanor, Plumas County, and south to Lake Tahoe, El Dorado County. Lassen County lies south of Modoc County and is bounded on the east by Nevada (Figure 1).

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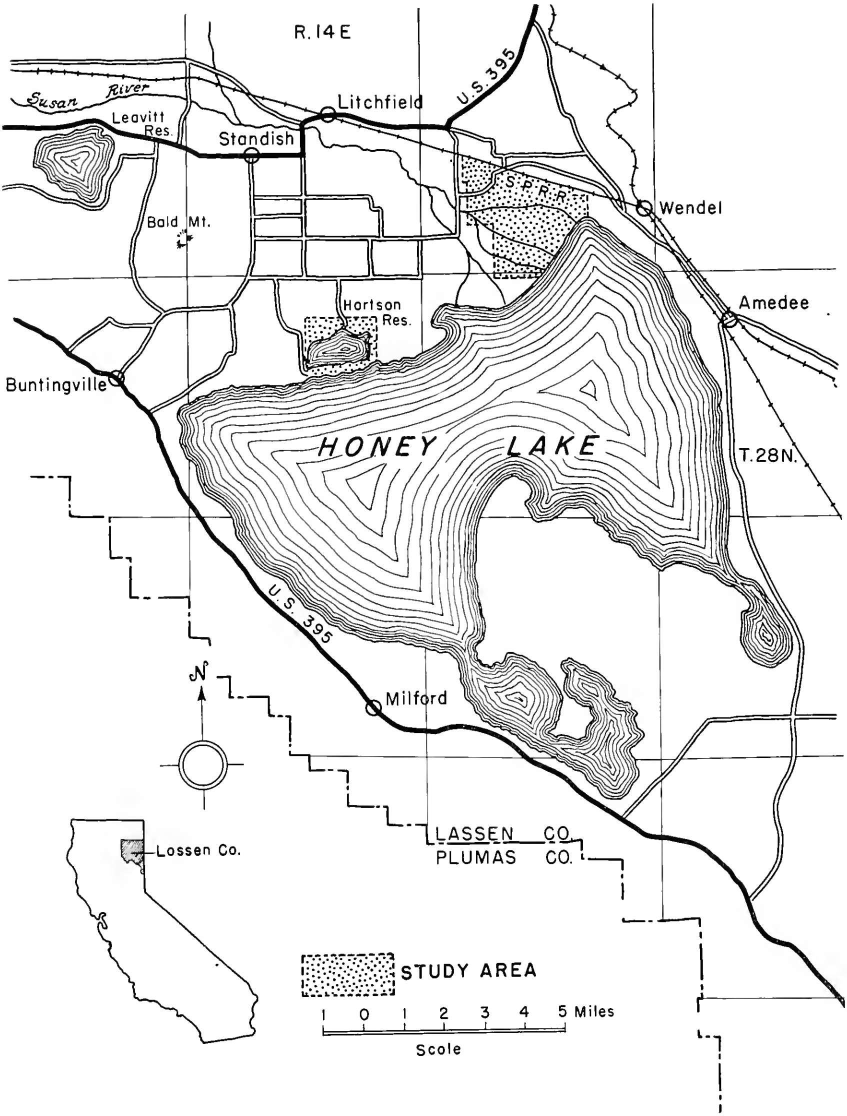

FIGURE 1. Map of Southeastern Lassen County, California, showing location of study area

Honey Lake Refuge is located about 23 miles east of the City of Susanville in the southeastern part of the county. The refuge lies on the floor of the valley and is on the north shore of Honey Lake. This lake usually becomes dry in the summer, but was full during the time of this study and contained water throughout 1951.

The Honey Lake Valley is typical of the Upper Sonoran life zone and is of the Great Basin sagebrush type described by Jensen (1947). The altitude of the refuge is approximately 4,000 feet. The average annual rainfall is about eight inches, with the largest part of the rain

falling between October and February. However, an abnormal rainfall occurred in November and December of 1950 to bring the water levels higher than they had been for many years. Thus, conditions were similar to those that occurred when Dow made his study.

The water supply feeding the valley comes from the Susan River, Willow Creek, Secret Creek, and many other small streams.

Common plants found in the area are alkali weed, sagebrush, willows, greasewood and rabbit brush. Emergent marsh vegetation includes bulrushes, rushes, sedges and some of the smartweeds. Aquatic vegetation includes sago pondweed, water milfoil and water buttercup. The most common grasses are salt grass, foxtail, rye grass and beard grass.

The common mammals present on the study area are the Rocky Mountain mule deer, coyote, striped skunk, Oregon ground squirrel and the black-tailed jackrabbit.

In addition to the Canada goose, waterfowl commonly nesting on the refuge are the mallard, pintail, cinnamon teal, shoveller, gadwall, redhead and ruddy duck. The more common wading birds are the western willet, avocet, black-necked stilt, long-billed curlew, killdeer, Wilson snipe and the Wilson phalarope.

The main agriculture of the valley is the production of meadow grasses and alfalfa which are cut, stored and used for winter feeding of cattle. A small amount of cereal crops is also grown.

The study area of Honey Lake Refuge consisted mainly of two large ranches: the Fleming Ranch of 2,100 acres of farmed area, artificial ponds and undisturbed land, and the Dakin Ranch of 1,425 acres of chiefly undisturbed land, a total of 3,525 acres. The total acreage of the refuge, however, is over 5,000 acres, but approximately 60 percent of the land is unsuitable as nesting cover and was not considered in the study. Of the 3,525 acres in the study area, approximately 2,000 acres were classified as nesting cover. The Dakin Ranch includes a large body of water called the Hartson Reservoir, and nearly all the nesting on the ranch is in the immediate vicinity of that reservoir. The complete area is managed for waterfowl and controlled public hunting of waterfowl and pheasants is allowed.

METHODS

For the purpose of this study the refuge was broken down into arbitrary units; i.e., a fenced-in field or a piece of land surrounded by a slough would constitute a unit. These units were searched systematically by two men walking a short distance apart. The distance between the men was determined by the type of cover on the unit.

As a nest was located it was given a number and the data were recorded on a nesting card with the same number. The nesting card was used to record all new information on return visits to the nests. A marker—a willow stake inserted in the ground near the nest, bearing the nest number—was used to facilitate the finding of the nest on return visits.

The type of marker used in this study proved very satisfactory for use in relocation of nests and may be of help to others working on nesting studies. Young willows of about one inch in diameter were the best, their length determined by the type of cover in which they were to be used (four or five feet was ideal for this study). The top of the stake

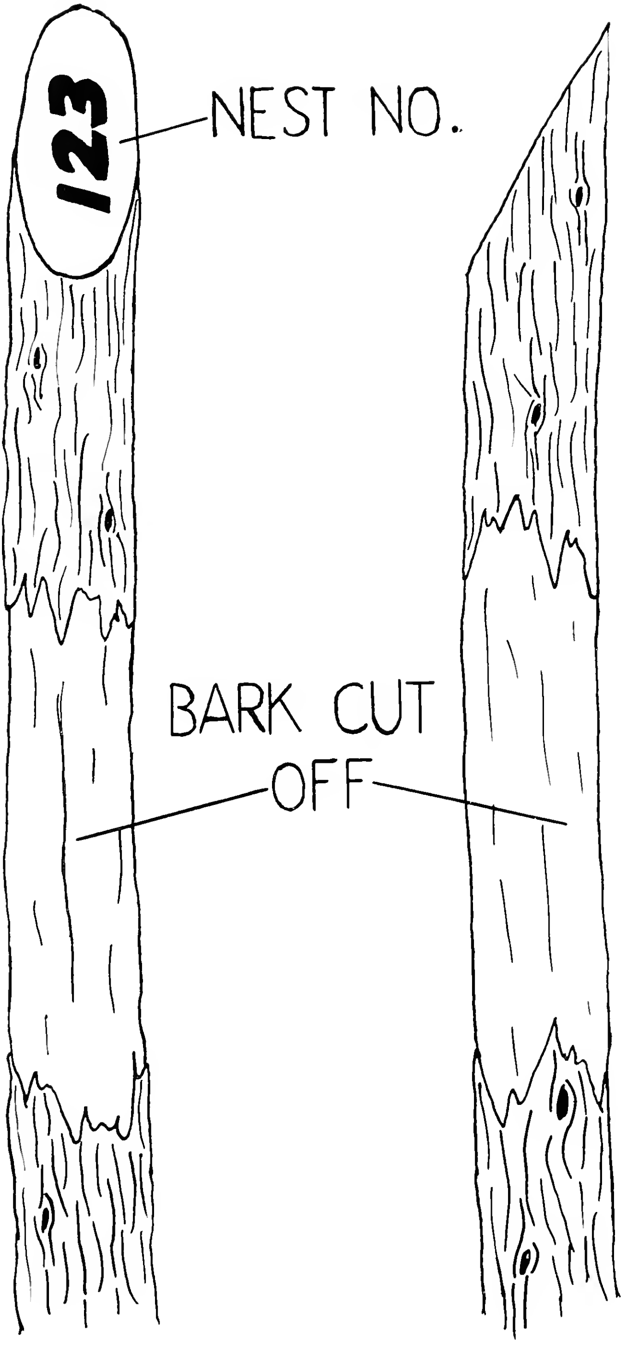

FIGURE 2. Willow stake used as nest marker, front and side views

was cut on an angle and the nest number written the length of the cut with a Presdon ball point pen (Figure 2). This ink is very permanent and survived three different rains and the complete nesting season without fading.

About five inches below the top of the stake the bark was scraped off, exposing about six inches of the white sapwood underneath. This facilitated locating the stake at a distance. Even after the white wood darkened or turned a light brown, the stake could be located easily. Some biologists are of the opinion that stakes with tags flashing in the wind tend to attract predators to the site. This type of marker blends well with the surrounding vegetation, but because of the light colored portion is readily visible without the movement which would attract predators. The stakes were placed about 15 feet from the nest and in line with prominent local landmarks.

NESTING DATES

The spring of 1951 was mild and about two weeks earlier than usual. The first nest was found on March 18th, containing seven eggs, and hatched 18 days later. The nest, then, was actually started during the first week of March. Nests with eggs were most numerous during the early part of April (Figure 3). The majority of the nests contained eggs and were under incubation by April 7th. The peak of egg-laying came between March 25th and April 10th. The peak of the hatch came between April 15th and April 30th. This compares favorably with the study made by Dow (1943).

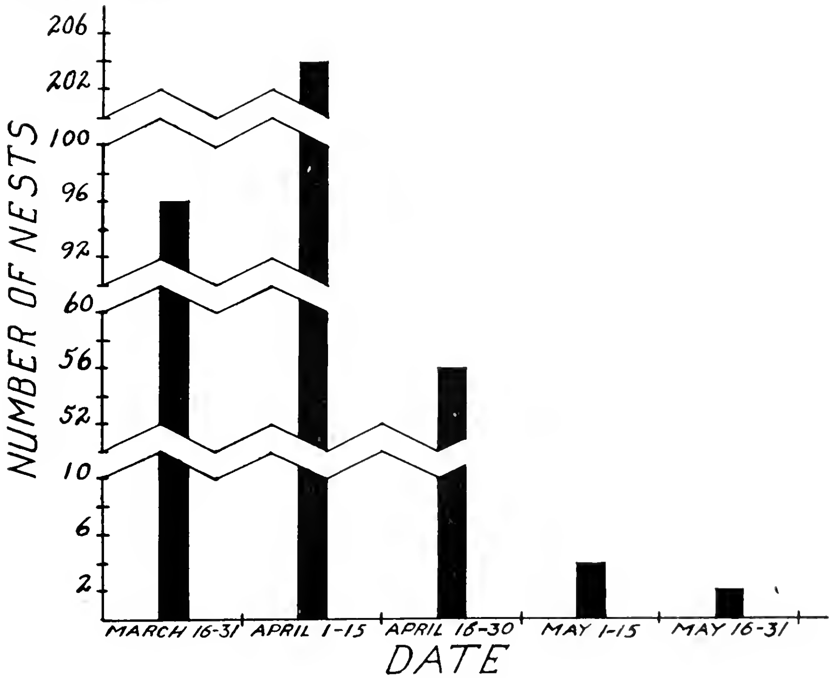

FIGURE 3. Periods when nests with eggs occurred at Honey Lake Refuge, Spring, 1951

Only two nest histories were incomplete after March 16th. One of these nests was started on May 8th and the female continued incubating six eggs until she deserted on June 15th. The eggs were opened and it was found that two were infertile. The other four had embryos that had died in very early stages of development. The female had incubated 39 days before deserting. This was believed to be a renesting attempt.

All nesting activity had ceased by June 16th and the nesting season was considered complete on that date.

Aside from the late nests mentioned above, the nesting period extended for about 60 days. Dow recorded a 65-day nesting period. Williams and Marshall (1937) found the nesting period at Bear River Marshes, Utah, to be 61 days. Kossack (1950) in Illinois reported a nesting period of 61 days in 1945 and 68 days in 1946. Two months apparently is the average length of the nesting season for this species of goose.

NESTING COVER

Since the nesting season of the Canada Goose in California starts early in March the vegetation had not started its spring growth, and the nest sites were readily located.

The high water during the spring of 1951 made available more cover for nesting. Much of the area remained under water of varied depths until early in May. This offered more protection to the nesting geese in many areas that normally would not be considered as nesting sites. The high water early in the spring left a large amount of water standing in the fields. High spots were surrounded by water at the beginning of the nest construction and egg laying periods. The high ground was utilized for nest sites. Also many areas that were normally dry and far from water were now available as good nesting cover as the result of water in the vicinity. As the nesting season progressed the water level dropped but without any detrimental effects to the geese. There was plenty of water still available for the broods at hatching time.

Nests were found in 17 different general cover types. Very definite preferences were shown among the 17 different types, with hardstem bulrush, islands and ditchbanks comprising about 75 percent of the total nesting sites (Table 1). Dow recorded only eight different cover types over a much larger area.

Some description of the cover is needed to qualify the different general types. There was overlapping of some cover types and when this occurred the dominant type was recorded. As an example—if a nest was located on an island and the cover immediately surrounding the nest was sagebrush, the nest site was recorded as island. Any piece of land, regardless of size, was recorded as island if entirely surrounded by water. Bulrush over water consisted of masses of hardstem bulrush emerging out of water of varied depths. Bulrush over land were masses of dried hardstem bulrush where there was no water standing. Any ditch running through an area with raised banks was classified as ditchbank cover type. There are artificial ponds impounded by levees on the refuge. These provided the geese with elevated nest sites and were classified as levee cover type. The pasture land and undisturbed land on the refuge is interspersed with stands of sagebrush and black greasewood cover

TABLE 1

General Cover Types—Used as Nesting Sites by Canada Geese

Cover type	Number of nests	Percent
Island	124	34.5
Bulrush over water (*Scirpus acutus*)	76	21.1
Ditchbank	42	11.7
Bulrush over land (*Scirpus acutus*)	28	7.8
Levee	17	4.7
Sagebrush (*Artemisia tridentata*)	15	4.2
Open field	13	3.6
Willow (*Salix* sp.)	9	2.5
Dirt mound	7	1.9
Black Greasewood (*Sarcobatus vermiculatus*)	5	1.4
Salt Grass (*Distichlis* sp.)	5	1.4
Alkali Bulrush (*Scirpus paludosus*)	4	1.1
California Wild Rose (*Rosa californica*)	4	1.1
Bur-reed (*Sparganium eurycarpum*)	3	0.8
Fence row	3	0.8
Muskrat house	3	0.8
Common Cattail (*Typha latifolia*)	2	0.6
Totals	360	100.0

types. Open field cover type refers to undisturbed areas, such as ungrazed pastures or uncultivated land. In one pond dirt mounds had been pushed up by bulldozer to accommodate loafing waterfowl. These mounds were not surrounded by water at the time of this study and are referred to as dirt mound cover type. The remainder of the cover types listed should be self-explanatory.

It is interesting to note that six nests were found built over old nests. Kossack (1950) found that many pairs used the previous year's nest site or nested within 100 feet of an old nest site.

There has been a noticeable change in agricultural practices since 1940 when Dow made his study. Alfalfa and meadow grasses are not cut and piled in loose stacks scattered about the valley as they were formerly. Now with modern machinery the hay is cut, baled and hauled to the stackyards and cattle feeding areas. This explains the contrast with Dow's finding 16 nests atop such haystacks while there were no nests located in that cover type in this study. Also, hay crops are not utilized or cultivated on the refuge.

EGG LAYING AND HATCHING

During the course of the study 369 nests were located and recorded. Seven nests had hatched when found and nesting cards of two nests were misplaced or lost, leaving a total of 360 nests with histories complete.

With such a large number of nests, the interval of 18 days between visits was the shortest time in which the entire area could be searched. This proved to be sufficient time, however, to record any new data occurring on a nest.

Since the object of this study was mainly to obtain data on production, no effort was made to determine egg-laying intervals, incubation time or other similar information.

A total of 1,904 eggs was produced from the 360 nests. This figure constitutes the total number of eggs laid during the study. A nest was

considered as having a full clutch if there was some stage of incubation present in a deserted nest, or if the nest hatched successfully. Full clutch nests totaled 330 and produced 1,828 eggs. The average size of the clutch was 5.53 eggs. This average was slightly higher than Dow (1943) found in 1939 (5.09) and in 1940 (5.10) on the same general area. The average clutch also compared closely to Kossack (1950) in Illinois where he found the average clutch of 73 nests to be 5.4 in 1947. Williams and Marshall (1937) recorded an average clutch of 4.8 for 84 nests.

The clutch size varied from 2 to 12 eggs. Nine nests had nine eggs each and two nests had 11 eggs each. The two with 11 eggs each hatched 10. One nest had 12 eggs and was incubated for 17 days before being broken up by a mammal. Three eggs were crushed and eaten and nine were scattered about the nest platform. On examination of the remaining eggs all seemed to be in the same stage of incubation. The writer believes that all these abnormally large clutches were the products of individual females and that no parasitism occurred.

Of the 360 nests, a total of 246 was hatched, or 68.3 percent were successful. This was better success than Dow found in 1939 (52.5 percent) and 1940 (60 percent).

The successful nests produced 1,360 eggs, and of these 1,127 hatched, for an 82.6 percent hatching success. This compared favorably with the data Williams and Marshall obtained at Bear River where they recorded 81 percent hatching success. Kossack recorded a much lower success in 1945 (41 percent) and 1946 (73 percent). Dow recorded a high success of 93 percent in 1940. These data seemed to indicate that the hatching success varied with the locality and other factors.

UNSUCCESSFUL NESTS

Unsuccessful nests were classified as being caused by either desertion or destruction. Desertion was approximately three times greater than destruction, with 28 nests or 7.8 percent destroyed as compared to 86 or 23.9 percent of the nests deserted (Table 2). Dow (1943) found 6.5 percent of the nests deserted in 1939 and 7.3 percent in 1940. The cause for such a large increase in desertion has not been definitely ascertained. One factor could be that the nesting population has increased as the development of the refuge increased, but the preferred nesting cover has not increased proportionately. Another possibility is that the gradual drying of Honey Lake during the last several years has forced the geese to nest away from the shore of the lake. This has made it necessary for the nesting pairs to nest in fairly close groups where the preferred cover occurs. The instinct to defend the territory is never forgotten and when nesting pairs are grouped together in a limited area many fights, quarrels and much loud calling occur among the pairs. This evidently results in many desertions.

As an example, the writer cites one island approximately 75 yards long and 30 yards wide, equal to about 0.5 acre. This island had a total of 31 nests. The greatest distance between any two nests was 30 yards and the shortest distance between any two was six feet. Eleven hatched, four were destroyed and 16 were deserted due to crowded conditions or unknown causes. It was on this island that the males stayed close to the females on the nest. The pairs very seldom left the area and then only to feed. There was always a great deal of calling and noise in the vicinity.

TABLE 2

Fate of Unsuccessful Nests

Cause	Number destroyed	Percent
Destruction		
Bird	10	35.8
Mammal	6	21.4
Flooded	6	21.4
Unknown	6	21.4
Totals	28	100.0

Cause	Number deserted	Percent
Desertion		
Crowded conditions	39	45.4
Human activity	8	9.3
Ants	2	2.3
Unknown	27	43.0
Totals	86	100.0

The pairs were nervous and fighting resulted upon intrusion in the small territories. The writer believes that the overcrowded conditions caused most of the desertions on this particular island. Those pairs that did bring off young often left the nest with the hatching of the first two or three young and deserted the remaining eggs. Two nests were constructed over anthills and were under incubation. However, the arrival of warmer weather brought out the ants and the nests were quickly deserted.

Due to the difficulty in determining the predator of a destroyed nest, the broad classification of bird or mammal was used. Mammalian predators known to destroy nests on the area were the coyote and striped skunk. The black-billed magpie, crow, and ring-billed and California gulls were the birds taking their toll of eggs.

Destruction by mammals may have been held to a minimum by an intensive trapping program by a state trapper prior to the nesting season. It is the opinion of some field men that if mammals are trapped heavily, predation by birds increases and vice versa. If this is true, it may explain the high amount of predation by birds in this study (Table 2).

EGG FERTILITY

A sample of 59 hatched nests was taken to determine fertility. The eggs remaining in the nest were classed as infertile if the yolks were still suspended and the nest had hatched. These nests produced 350 eggs of which 110 eggs were left in the nest after hatching. Of these 110 eggs, 7 or 2.0 percent of total eggs in the sample were infertile.

MISCELLANEOUS INFORMATION

In the course of this study various abnormalities were recorded. Two nests were recorded as having a small egg or so-called pullet egg in the

clutch. In one nest the eggs hatched but the pullet egg remained with the yolk suspended and proved to be infertile. The other nest was destroyed. Thus the chance to determine the possibility of fertility in the small eggs and to observe the product of such an egg was lost.

A single mallard egg was found in two of the nests. Both nests hatched, leaving the duck eggs in the nest. In both instances no development occurred in the duck eggs. Since the deposition of the eggs in the goose nests occurred early in the season, the nests apparently served as dump nests for the dropped duck eggs.

A dead muskrat was found in a goose nest which had four eggs under incubation. The cause of the muskrat's death was not determined but the writer feels that this intrusion caused the hen to desert her nest.

The habits of the nonbreeding geese are not well understood. The general consensus is that the nonbreeders remain in small groups on the nesting ground throughout the breeding season without pairing. Observation of the small groups of nonbreeders during this study, however, leads the writer to believe that some of the nonbreeders pair in their second year of life but do not breed until the third year. The middle of the nesting season found the small groups loafing and feeding in the same general area every day. They showed no nesting behavior at all, but when flushed they repeatedly broke into pairs to fly away or remained in pairs away from the other groups of geese. This phenomenon occurred throughout the study and the number of geese involved was too large to assume they were all pairs from broken nests.

MANAGEMENT

Possible avenues of management practices which might increase the number of Canada geese produced at Honey Lake Refuge are discussed below. This study seems to indicate that there is a definite need for island type nesting cover—a raised mound surrounded by water and containing some type of vegetation suitable for nest construction and cover. Table 3 shows the nesting success for the preferred cover types. Since all islands had large numbers of geese nesting, the rate of desertion was high even excluding the one island with an unusual high concentration of nests, and hatching success fell below that noted for bulrush over water and ditchbank cover types. Evidently the high rate of desertion was caused by overcrowding on the existing islands that had suitable nesting cover. The construction of islands would relieve the crowded nesting conditions by spreading the existing nesting population over a larger area, and more geese would be produced by a greater number of nests hatching successfully. The manner of construction, the type and number of islands built should be left to the discrimination of the refuge manager.

Prenesting season predator control may be a useful management practice. Prior to the nesting season of 1951 a state trapper was headquartered on the refuge. He concentrated mainly on trapping nest predators and it is believed that his efforts contributed to the low number of nests destroyed by mammals. A study of waterfowl nesting in the Sacramento Valley also found that decreased nest success resulted from decreased local predator control (C. S. Williams and others, 1950).

TABLE 3

Nesting Success of the Three Main Cover Types

Fate	Islands*		Bulrush over water		Ditchbank	
	No. of nests	Percent	No. of nests	Percent	No. of nests	Percent
Hatched	59	64	57	75	28	66
Deserted	24	26	13	17	7	17
Destroyed	10	10	6	8	7	17
Totals	93	100	76	100	42	100

* Exclusive of island with abnormally high desertion rate. See text

The opening of dense vegetative growth on the levees of some of the artificial ponds would provide nesting pairs with greater visibility. The visibility factor seems to have a definite influence on the choice of a nest site. During the fall of 1950 the writer posted the refuge for the pheasant and duck hunting seasons. The closed area boundary followed along a levee which had a very heavy vegetative growth of alkali weed. A pickup truck was used to do the posting and as a result some of the levee vegetation was smashed down by the truck. The following spring the geese utilized the section of the levee the truck had been through, but levees adjacent with identical growth still standing were not used at all as nesting cover.

SUMMARY

The nesting season of 1951 was about two weeks earlier than in 1950. Most nests were under incubation by April 7th. The peak of egg laying came between March 25th and April 10th. The peak of the hatch came between April 15th and April 30th.

Seventeen different cover types were used for nesting. Hardstem bulrush, islands and ditchbanks comprised 75 percent of the total nest sites. The high water level made available much more nesting cover than usual.

A total of 360 nests produced 1,904 eggs. The average clutch size was 5.53 eggs. Of the 360 nests, 68.3 percent were successful. The hatching success of the eggs was 82.6 percent.

Desertion accounted for 23.9 percent of the unsuccessful nests and destroyed nests accounted for 7.8 percent.

A sample of 59 nests showed 2 percent of the eggs were infertile.

It is believed possible to increase the number of geese produced annually on Honey Lake Refuge by preseason predator control, construction of islands and control of vegetation.

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NUMBERS AND WINTER DISTRIBUTION OF PACIFIC BLACK BRANT IN NORTH AMERICA[1]

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The Pacific black brant (*Branta nigricans*) breeds on the Bering and Arctic coasts of North America and in northeastern Siberia. One segment of the population, presumably composed largely or entirely of birds breeding in Alaska (Spencer *et al.*, 1951) and northwestern Canada, migrates in winter to Pacific shores of this continent, from southern Alaska to Baja California. The winter distribution of black brant in North America was made the subject of exhaustive study by the late James Moffitt, whose annual brant census reports for the years 1931 to 1943 accurately designate all the major wintering areas in the continent and many of the minor ones. However, Moffitt's census data, which were taken regularly only in California, include incomplete and at best sporadic notes on brant numbers wintering to the north and south. At no time was an integrated survey made of the whole winter range which would yield a reliable figure for the population in North America. In the course of the 1952 winter inventory of North American waterfowl, conducted under the auspices of the U. S. Fish and Wildlife Service with the cooperation of state and provincial wildlife agencies, a reasonably complete count of Pacific black brant was obtained. It is our purpose here to record this information.

Small numbers of brant winter on the Pacific coast of Asia—presumably the same birds that breed in northeastern Siberia, though this assumption has not been verified. Dresser (1903) characterizes the Asiatic winter range as "from Kamchatka . . . to Japan." Austin (1949) cites 12 specimen records from Japan and states that the species "was formerly a common winter visitor to Japan but is now exceedingly scarce." The same author (1948) designates the brant as "an uncommon winter visitor" in Korea. La Touche (1931-34) writes as follows of the brant on the coast of China: "A single bird was sent to me from Foochow which had been shot on the 4th of February. The Pacific Brent Goose, which winters in Japan and down to California, therefore extends its winter range to the China coast as far south as Fohkien. It must, however, be extremely rare in the Formosa Channel, as neither Rickett nor I ever heard of the bird's occurrence during the time that we were stationed at Foochow." Likewise Thayer and Bangs (1914) state that the black brant is an uncommon breeder on the Siberian Arctic coast. Our immediate concern is with the brant population that winters in North America, but the above records are cited to indicate the apparent scarcity of the bird in Asia and the fact that we probably have in North America the vast majority of the population of *B. nigricans*.

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[1] Submitted for publication July, 1952.

SOURCES OF DATA

During the period January 6 to 13, 1952, the authors in company with Wynn G. Freeman of Montana Fish and Game Commission, made a detailed aerial count of brant along virtually the whole coast from Humboldt Bay in Northern California to San Ignacio Bay in southern Baja California. The coast from San Ignacio Bay south to Magdalena Bay was not covered in 1952 but had been flown by Smith in 1950, so the brant figure for that year was used to complete the count for the southern wintering range. Two areas in California, where small numbers of brant are known to winter, were not censused in 1952, namely, San Diego and Mission Bays in the south and the north coast from Humboldt Bay to the Oregon line. Doubtless a few birds were missed in these areas. No allowance was made for the omission. In the area which we did census, approximately 88 percent of the continental population of black brant was found to winter.

Our counts were all visual estimates, taken from an airplane flying at elevations of 150 to 200 feet. Brant lend themselves exceptionally well to aerial census for the following reasons: (1) Flocks usually are small (50 to 500 birds) and tend to be well deployed along the shores of suitable bays and estuaries. (2) When disturbed the birds normally fly toward open water and can be counted more or less accurately as they pass in front of the airplane. (3) They do not return immediately to the shallow feeding areas, where they could be confused with birds not yet counted, but instead usually settle in open water. Thus, in censusing the brant on a big bay like Scammon Lagoon one simply flies the full shoreline in all its indentations and counts the birds as they pass at right angles in front of the airplane. At the end of the census virtually all the brant are gathered in the middle of the bay. It is probable, of course, that some flocks are missed and it is equally probable that others quarter into unworked ground where they are counted a second time. But these two errors would tend to be compensating, and it is our personal feeling that the counts are much more accurate than most visual estimates of waterfowl numbers.

Simultaneously with our survey of the California and Mexican coasts, counts of waterfowl including brant were being taken in Oregon, Washington, British Columbia and Alaska. Summaries of these data were supplied by Joseph P. Linduska of the U. S. Fish and Wildlife Service and by David A. Munro of the Canadian Wildlife Service. We are grateful to these colleagues [2] and to the many state and provincial wildlife officers who actually made the counts in the field, for allowing us thus to complete our report on total black brant numbers in the continent. Some of the supplementary counts from northern areas were taken from the air but others were ground or boat counts of unknown accuracy. Certain localities in British Columbia, where a few brant have been known to winter in the past, could not be visited at all. However, the number of birds wintering along northern shores is so small compared to the population found farther south that no appreciable error could be involved in the total figures as given below.

[2] The senior author likewise is indebted to the Duck Hunters Association of California for sponsoring his participation in the 1952 survey.

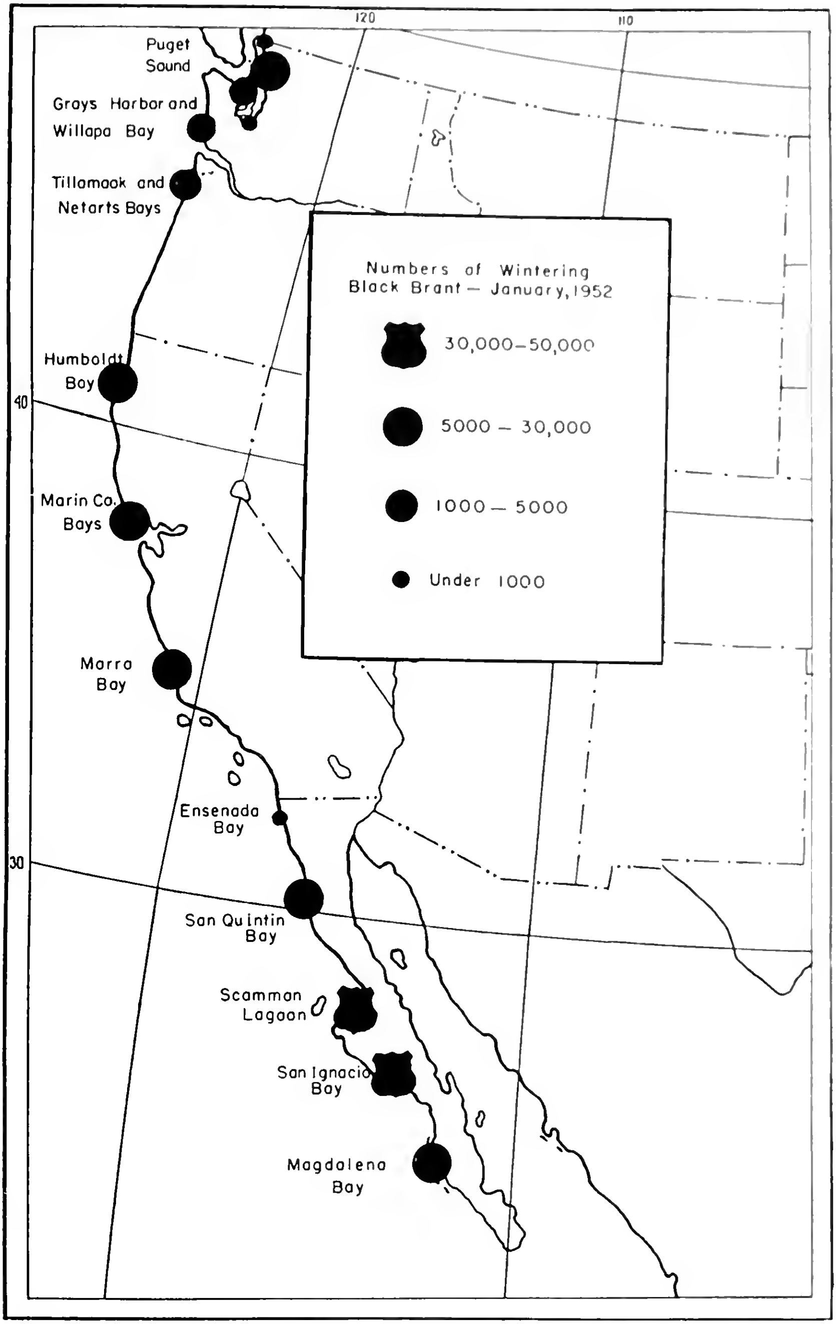

FIGURE 1. Winter distribution of Pacific black brant in North America, as determined in January, 1952.

BRANT NUMBERS IN 1952

Table 1 summarizes by locality, and by state or province, the 1952 winter inventory figures for black brant in North America. Figure 1 presents the same data on a map which encompasses all but a few minor wintering areas in the extreme north. The total population was determined to be 174,740, of which 109,545 (63 percent of the birds) were found in Baja California, 43,840 (25 percent) were in California, 16,575 (9 percent) were in Washington, and the remaining 4,780 birds (3 percent) were scattered along the coasts of Oregon, British Columbia and southern Alaska.

The importance of Baja California as a brant wintering area was recognized by Nelson (1921), who stated that some of the bays on the Pacific side of the peninsula were the "main winter home" of the species.

TABLE 1

Numbers and Locations of Black Brant Inventoried in January, 1952, by the U. S. Fish and Wildlife Service and Cooperating State and Provincial Wildlife Agencies

Area	Local numbers of brant	State or provincial totals
Southeastern Alaska	80	
		80
British Columbia		
Masset, Queen Charlotte Islands	1,000	
Boundary Bay	500	
		1,500
Washington		
Puget Sound: Birch and Boundary Bays	550	
Puget Sound: Samish and Padillo Bays	10,000	
Puget Sound: Washington Harbor and Dungeness Spit	2,000	
Puget Sound: Hood Canal	1,650	
Puget Sound: Nisqually Flats	500	
Grays Harbor	640	
Willapa Bay	1,235	
		16,575
Oregon		
Tillamook and Netarts Bays	3,200	
		3,200
California		
Humboldt Bay	25,000	
Marin County Bays: Bodega Bay	235	
Marin County Bays: Drakes Bay	2,170	
Marin County Bays: Tomales Bay	7,900	
Marin County Bays: Bolinas Bay	535	
Morro Bay	8,000	
		43,840
Baja California		
Ensenada Bay	465	
San Quintin Bay and nearby coast	13,650	
Rosario Bay	580	
Scammon Lagoon	46,500	
San Ignacio Bay	41,750	
Magdalena Bay and nearby coast (1950 figure)	6,600	
		109,545
Total black brant wintering in western North America		174,740

The figures in Table 1 verify this observation, Scammon Lagoon and nearby San Ignacio Bay actually containing between them 88,250 birds or slightly over half the continental population. Both of these bays include great areas of shallow water, covered with extensive beds of vegetation which from the air appears to be eelgrass (*Zostera marina*), the main winter food of sea brants (Cottam *et al.*, 1944). Smaller bays of like character at San Quintín to the north and near Cape San Lazaro (north of Magdalena Bay) to the south were occupied by another 20,000 brant, with a few hundred additional birds scattered along the peninsula in coves or lagoons. Fortunately none of the important brant bays in Baja California are being developed or altered in any way, in fact only a handful of fisherman live on these shores. We foresee every prospect, therefore, of perpetuation of the brant wintering grounds in Baja California, assuming of course that there is no outbreak of disease (*Labyrinthula*) in the eelgrass beds such as occurred on the coast of California in 1940-41 (Moffitt, 1941 and 1943).

The important brant wintering grounds in California are Humboldt Bay, the several bays in Marin County (especially Drakes and Tomales) and Morro Bay. Formerly San Diego and adjoining Mission Bays in the south were fairly important, but pollution, dredging and other developments, plus continual disturbance by boats and airplanes, have rendered this area of less use to brant. Some other California bays have been affected to a minor extent by similar developments (especially Humboldt Bay) but not to the point where the brant are driven away.

The only other area of any importance to wintering brant is Puget Sound, which furnishes favorable winter range for about 15,000 birds.

When the brant begin their slow northward drift in early spring they frequent many other localities along the Pacific Coast not mentioned in the above paragraphs. However the January distribution as we have described it probably accounts for all but a few scattered flocks.

DISCUSSION

A species represented by a continental population of only 174,740, or perhaps slightly more individuals, certainly cannot be construed as abundant. Yet because of their oceanic habits and inaccessibility to hunters, black brant do not suffer an excessively heavy kill. Such at least was the opinion of Moffitt (1940), and we have no evidence to the contrary. Since Moffitt's time, shooting restrictions have been somewhat altered in favor of the brant hunter (later seasons, earlier shooting hours, increase in the daily bag from two to three birds in 1951) and the kill doubtless has increased. The computed kill in California for the years 1948 through 1951, for example, was in the neighborhood of 16,000 birds per year according to information obtained from a questionnaire of hunters (data supplied by J. E. Chattin, California Dept. of Fish and Game). A similarly computed kill in British Columbia was 6,200 birds bagged in 1950-51 (letter from D. A. Munro). Although these figures almost certainly are exaggerated, as is usually the case with hunter questionnaires, they indicate that the kill is by no means negligible. However, there is no clear indication of any general decrease in brant numbers. The 1952 total for California (43,840 birds) is materially lower than Moffitt's 11-year average count of 57,365, but this may be

happenstance since the year-to-year winter brant figures for any given locality were found by Moffitt to vary enormously with irregularities in weather and migration.

In the past winter (1951-52) there has been a sudden increase of brant damage to crops in California. According to Clinton Lostetter, U. S. Fish and Wildlife Service, Berkeley, pastures and winter grain-fields near Humboldt and Tomales Bays were invaded by large flocks of the birds, and near Morro Bay the brant caused local damage to truck crops (especially peas) as well as to pasture and grains. This curious invasion of crop lands by brant is precisely parallel to what occurred in 1940-41 when the eelgrass beds were attacked by the disease organism *Labyrinthula* (Moffitt, 1941). To our knowledge no one is currently checking on the status of Pacific Coast beds of eelgrass, but this certainly should be done as background for future brant hunting regulations. Crop damage by black brant may signify a loss of carrying capacity in the natural feeding areas rather than any increase in brant numbers.

SUMMARY

The 1952 winter inventory of North American waterfowl yielded a reasonably complete census of Pacific black brant. The total observed population of 174,740 birds was distributed as follows: 63 percent in Baja California, mostly in Scammon Lagoon and San Ignacio Bay; 25 percent in California, mostly in Humboldt Bay, Marin County bays and Morro Bay; 9 percent in Washington, nearly all in Puget Sound. The remaining 3 percent were scattered along the coasts of Oregon, British Columbia and southeastern Alaska.

All of the principal wintering areas in Baja California and most of those along United States and Canadian coasts are remaining essentially habitable to brant, with little apparent alteration or serious destruction of necessary habitat. However, a sharp increase in crop damage by brant may signify a decrease in normal supplies of eelgrass, which situation should be studied as a guide to future brant hunting regulations. There is a suggestion of increasing hunting pressure on the species but no evidence as yet of overshooting.

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STATE-WIDE CALIFORNIA ANGLING ESTIMATES FOR 1951 [1]

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It is the practice in California to make periodic state wide angling surveys, using postal card questionnaires. They provide estimates of sport fish catches and angling pressure, principally for fresh water and anadromous species. Questionnaires are sent to a random sample of all licensees. Methods have been described earlier (Calhoun, 1950).

Table 1 summarizes the characteristics of the 1951 survey. It resembled the 1949 one (Calhoun, 1951) in most respects. The principal difference was an unusually large response in 1951: 35.9 percent instead of the usual 30 percent. This may well reflect an improvement in the department's public relations.

The results of the 1951 survey are summarized in Table 2, and discussed briefly below by kinds of fish and by departmental administrative regions.

It must be emphasized that these figures are only rough estimates. Their reliability is discussed at some length in the earlier report already mentioned (Calhoun, 1950).

1951 CATCH RECORDS BY KIND OF FISH

Trout

Anglers caught an estimated 18,600,000 trout in California in 1951. This figure has remained relatively static since 1946. The number of anglers catching trout in 1951 was 429,000. Their mean annual catch

[1] Submitted for publication August, 1952.
[2] The assistance of Terrence Merkel and William Rowley with calculations is gratefully acknowledged.

TABLE 1

Characteristics of the 1951 Sample

1951 angling license sales	1,015,246[1]
Questionnaires mailed[2]	7,998
Sampling level desired	0.8%
Sampling level attained	0.79%
Questionnaires returned	2,870 (35.9%)
Conversion factor (1,015,246 ÷ 2,870)	353.7
Respondents who caught something	2,299 (80.1%)
Respondents who fished unsuccessfully	361 (12.7%)
Unsuccessful, may or may not have fished	97 (3.4%)
Did not fish	110 (3.8%)
Average fishing days per licensee	15

[1] Not the final figure, but believed correct within about 400.
[2] The tenth license stub in each fifth book of 25 was selected.

TABLE 2

California State-wide Angling Estimates for 1951

	Trout	Striped bass	Black bass	Crappie	Sunfish	Catfish	Salmon	Abalone
Postal card reports	1,214	406	305	215	288	484	223	117
Successful anglers	429,000	144,000	108,000	76,000	102,000	171,000	79,000	41,000
Standard error	9,360	6,600	5,840	4,990	5,690	7,100	5,070	3,740
Percent of all licensees	42	14	11	7	10	17	8	4
Mean annual catch	43.3	10.4	11.9	31.3	47.1	27.5	7.2	12.4
Standard deviation	64.7	16.2	20.3	62.8	101.6	55.8	8.73	14.8
Standard error of mean	1.86	0.80	1.16	4.27	5.99	2.54	0.58	1.36
Median annual catch	20	5	6	12	20	12	3	9.5
Total annual catch	18,600,000	1,490,000	1,280,000	2,380,000	4,800,000	4,710,000	564,000	515,000
Standard error	895,000	134,000	142,000	359,000	667,000	475,000	58,700	72,400

was 43 fish. The median catch, more descriptive of average success, was 20 fish. These estimates are much like those for 1948 and 1949, as will be seen from Table 3. Addition of anglers who fished for trout but caught none would have reduced the median catch from 20 to about 12, judging from the 1948 personal interview survey.

TABLE 3

Trends in California Trout Angling

Year	Total catch	Successful anglers		Average catch per successful angler	
		Number	Percent of angling licenses	Mean	Median
1936	12,000,000	119,000	50	80	[illegible]
1937	11,900,000	151,000	48	78	[illegible]
1938	12,900,000	160,000	46	79	[illegible]
1939	12,800,000	179,000	49	71	37
1941	15,700,000	238,000	53	66	40
1942	16,400,000	234,000	51	70	42
1943	15,700,000	213,000	48	73	37
1946	17,660,000	357,000	47	49	25
1948	18,100,000	415,000	43	44	20
1949	16,700,000	431,000	43	39	
1951	18,600,000	429,000	42	43	20

Striped Bass

The 1951 striped bass figure was 1,490,000 fish. This estimate has remained quite stable since 1942, as will be seen from Table 4. The 144,000 anglers catching stripers in 1951 represent a slight decline from 1949.

The average annual catch of 10 fish and the median catch of five fish are typical of the post-war period.

TABLE 4

Trends in California Striped Bass Angling

Year	Total catch	Successful anglers		Annual catch per successful angler	
		Number	Percent of angling licenses	Mean	Median
1936	2,110,000	84,100	28	25	
1937	2,040,000	81,900	26	25	
1938	1,910,000	92,800	27	21	
1939	1,880,000	89,300	24	21	12
1941	1,910,000	106,000	23	18	10
1942	1,680,000	88,200	20	19	
1943	1,680,000	75,000	17	22	9
1944	1,420,000				
1946	1,380,000	113,000	15	12	6
1948	1,650,000	161,000	17	10	5
1949	1,750,000	165,000	17	11	5
1951	1,490,000	144,000	11	10	5

Black Bass

There has recently been a slump in black bass fishing. The 1951 catch was only 1,280,000; compared with 1,890,000 in 1948. Past records are summarized in Table 5. Anglers catching black bass and average catches have also declined. The recent series of abnormally dry years has probably been largely responsible. This drought seriously reduced many Southern California reservoirs, which produce a large part of the bass catch.

TABLE 5

Trends in California Black Bass Angling

Year	Total catch	Successful anglers		Annual catch per successful angler	
		Number	Percent of angling licensees	Mean	Median
1936	930,000	34,000	11	27	--
1937	849,000	33,000	11	26	--
1938	1,190,000	46,000	13	26	--
1939	1,340,000	67,000	18	20	--
1941	1,530,000	75,000	17	20	--
1942	1,340,000	66,000	15	20	--
1943	1,570,000	79,000	18	20	--
1946	1,700,000	104,000	14	16	--
1948	1,890,000	128,000	13	15	6
1949	1,160,000	116,000	12	10	5
1951	1,280,000	108,000	11	12	6

Crappie

Crappie fishing has also declined, as will be seen from Table 6. Only 7 percent of all respondents reported catches in 1951, compared with 11 to 17 percent in earlier surveys. The total catch of 2,380,000 was taken by 76,000 anglers who averaged 31 fish per year.

The crappie catch is even more sharply localized in Southern California than black bass, and this decline is also largely attributable to the drought conditions already mentioned.

TABLE 6

Trends in California Crappie Angling

Year	Total catch	Successful anglers		Annual catch per successful angler	
		Number	Percent of angling licensees	Mean	Median
1939	1,720,000	52,000	14	33	--
1941	2,180,000	70,000	15	31	--
1942	2,620,000	66,000	15	40	--
1943	2,670,000	76,000	17	35	--
1946	3 040,000	106,000	14	29	--
1948	2,760,000	116,000	12	24	12
1949	2,430,000	105,000	11	23	10
1951	2,380,000	76,000	7	31	12

Sunfish

There was little change in the sunfish picture in 1951. A total of 4,800,000 fish was caught by 102,000 anglers, who averaged 47 sunfish per year. However, only 10 percent of all licensees caught these fish. This is the lowest percentage on record, as shown in Table 7.

TABLE 7

Trends in California Sunfish Angling

Year	Total catch	Successful anglers		Annual catch per successful angler	
		Number	Percent of angling licensees	Mean	Median
1939	2,090,000	51,000	14	41	
1941	2,770,000	63,000	14	44	
1942	3,060,000	57,000	13	54	
1943	3,040,000	68,000	15	45	
1946	4,320,000	122,000	16	35	
1948	4,820,000	118,000	12	41	20
1949	4,020,000	114,000	11	35	20
1951	4,800,000	102,000	10	47	20

Catfish

There was some improvement in the catfish situation in 1951. An estimated 171,000 anglers caught 4,710,000 fish. Past catfish records are summarized in Table 8.

TABLE 8

Trends in California Catfish Angling

Year	Total catch	Successful anglers		Annual catch per successful angler	
		Number	Percent of angling licensees	Mean	Median
1936	2,940,000	38,000	13	78	
1937	2,810,000	43,000	14	65	
1938	3,480,000	48,000	14	72	
1939	4,330,000	75,000	20	58	
1941	6,100,000	97,000	21	63	
1942	8,250,000	110,000	25	75	
1943	7,060,000	101,000	23	70	
1946	6,530,000	149,000	19	44	
1948	5,560,000	182,000	19	31	15
1949	3,930,000	161,000	16	24	12
1951	4,710,000	171,000	17	28	12

Salmon

Interesting changes are occurring in the salmon sport fishery. The 1951 catch of 564,000 fish is the largest on record, as will be seen from Table 9. The 79,000 successful anglers is also a new record, and the average catch of seven fish per year is high for the postwar period. Both

river and ocean fishing for salmon were involved in these changes, judging from the regional analysis which follows.

TABLE 9

Trends in California Salmon Angling

Year	Total catch	Successful anglers		Annual catch per successful angler	
		Number	Percent of angling licensees	Mean	Median
1936	196,000	25,000	8	8	--
1937	160,000	20,000	6	8	--
1938	178,000	22,000	6	8	--
1939	215,000	31,000	8	7	--
1941	253,000	38,000	8	7	--
1942	180,000	32,000	7	6	--
1943	274,000	31,000	7	9	--
1946	291,000	50,000	7	6	--
1948	321,000	65,000	7	5	2
1949	298,000	67,000	7	4	2
1951	564,000	79,000	8	7	3

Abalone

Abalone were added to the postal card questionnaire for the first time in 1951. The department now has a special investigation of these mollusks under way.

An estimated 41,000 individuals took 515,000 abalone for an average of 12 per year.

Abalone records from a 1948 personal interview survey, hitherto unpublished, are included in Table 10 for comparison. There may have been a decline of some magnitude in this fishery since 1948. However, these estimates are based on relatively few reports, and with only two years of records available it will be well to reserve judgment.

TABLE 10

Abalone Catch Records

Year	Total catch	Successful anglers		Annual catch per successful angler	
		Number	Percent of angling licensees	Mean	Median
1948[1]	1,400,000	65,000	7	22	--
1951	515,000	41,000	4	12	9.5

[1] Based on 85 reports.

1951 CATCH RECORDS BY ADMINISTRATIVE REGIONS

Northern Region (1)

This covers the extreme northern portion of California, as shown in Figure 1. It provided about half of the state salmon catch and about one-fifth of the trout in 1951. Many of the latter were large steelhead.

FIGURE 1. Department of Fish and Game administrative regions.

The average catch of 45 trout per year topped any other region. Other fisheries are of negligible importance, as will be seen from Table 11.

An estimated 44,170 anglers (4.4 percent) lived here [3] in 1951.

TABLE 11

1951 Angling in Region 1

	Number of reports	Regional catch		Successful anglers for indicated fish		Mean catch per successful angler in region
		Total[1]	Percent of State catch	Number in region	Percent of State total	
Salmon	84	236,000	46.4	30,000	39.7	7.9
Trout	244	3,900,000	21.8	86,000	17.3	45.2
Black bass	10	80,000	6.4	4,000	4.3	25.0
Sunfish	5	21,000	0.5	2,000	1.9	12.0
Catfish	15	120,000	2.7	5,000	2.8	22.6
Abalone	2	6,000	1.2	1,000	2.2	8.0

[1] The combined regional totals are ordinarily less than the state total because a few reports fail to specify county of catch.

Sacramento Region (2)

This includes the Sacramento Valley and the northern Sierra Nevada. It provided half of the 1951 striped bass catch and a sixth of the trout. It was also an important warm-water area, contributing half the catfish catch, a fourth of the black bass, and about a fifth of the crappie and sunfish. (For further details see Table 12.)

An estimated 129,730 anglers (12.8 percent) lived here in 1951.

TABLE 12

1951 Angling in Region 2

	Number of reports	Regional catch		Successful anglers for indicated fish		Mean catch per successful angler in region
		Total	Percent of State catch	Number in region	Percent of State total	
Salmon	17	18,000	3.5	6,000	7.9	3.0
Trout	251	3,135,000	17.5	89,000	17.1	35.3
Black bass	81	300,000	23.8	29,000	31.8	11.0
Crappie	38	435,000	18.7	13,000	16.6	32.3
Sunfish	73	842,000	17.9	26,000	25.0	32.6
Striped bass	200	700,000	47.3	73,000	49.6	9.9
Catfish	190	2,178,000	50.7	67,000	38.5	32.4

Bay Region (3)

This extends over the central coastal portion of the State from Mendocino County to San Luis Obispo County. Its sport fisheries are highly diversified, as will be apparent from Table 13. Significant catches in all eight categories were made in 1951, including half or more of the

[3] Based on the number of regional residents in the sample of 7,998 licensees to whom questionnaires were sent. There were 0.9 percent out-of-state anglers in our sample.

TABLE 13

1951 Angling in Region 3

	Number of reports	Regional catch		Successful anglers for indicated fish		Mean catch per successful angler in region
		Total	Percent of State catch	Number in region	Percent of State total	
Salmon	109	254,000	19.9	39,000	41.7	6.6
Trout	153	1,767,000	9.9	53,000	10.8	32.6
Black bass	52	170,000	13.5	18,000	16.7	[illegible]
Crappie	32	177,000	7.6	11,000	[illegible]	[illegible]
Sunfish	18	511,000	[illegible]	17,000	16.3	32.8
Striped bass	191	770,000	52.0	70,000	47.6	11.2
Catfish	113	709,000	[illegible]	40,000	22.9	17.7
Abalone	75	270,000	52.3	27,000	61.3	10.1

salmon, striped bass and abalone. The salmon catch comes principally from the Pacific Ocean off the Golden Gate. The trout catch include many large steelhead. Region 3 is also producing some warm-water fish.

An estimated 301,610 anglers (29.7 percent) live in Region 3.

San Joaquin Region (4)

This region covers the San Joaquin Valley and the southern Sierra Nevada. It yielded a fifth of the state trout catch in 1951, and a like proportion of black bass, sunfish and crappie. These data are summarized in Table 14.

Salmon have been much more important here in the past than they were in 1951. The agricultural development of this region, with ever-increasing water diversions for irrigation and growing water pollution from food processing plants is clearly having serious repercussions.

An estimated 115,640 anglers (11.4 percent) live in this region.

TABLE 14

1951 Angling in Region 4

	Number of reports	Regional catch		Successful anglers for indicated fish		Mean catch per successful angler in region
		Total	Percent of State catch	Number in region	Percent of State total	
Salmon	1	1,000	0.1	400	0.5	3.0
Trout	320	3,560,000	19.9	113,000	22.7	31.5
Black bass	69	230,000	18.3	24,000	26.3	9.6
Crappie	36	187,000	8.0	13,000	12.5	14.7
Sunfish	57	1,000,000	21.4	20,000	19.2	49.7
Striped bass	10	12,000	0.8	4,000	2.7	3.5
Catfish	76	731,000	17.1	27,000	15.5	27.3

Southern Region (5)

This includes Southern California and the Mono-Inyo area; as shown in Figure 1. Trout are of primary importance, as will be seen from Table 15. Some 150,000 anglers fished for them in Region 5 during 1951 and caught an estimated 5,500,000. This was about one-third of the state total.

TABLE 15

1951 Angling in Region 5

	Number of reports	Regional catch		Successful anglers for indicated fish		Mean catch per successful angler in region
		Total	Percent of State catch	Number in region	Percent of State total	
Trout	435	5,508,000	30.8	154,000	31.0	35.8
Black bass	46	480,000	38.1	16,000	17.5	30.9
Crappie	115	1,516,000	65.6	41,000	52.5	37.3
Sunfish	110	2,280,000	48.7	39,000	37.5	58.6
Catfish	98	558,000	13.0	35,000	20.1	16.1
Abalone	46	240,000	46.5	16,000	36.3	14.8

Southern California proper and Mono-Inyo are very distinct areas; so the trout data for the two were separated as shown in Table 16. There were more anglers and the level of success was higher in Mono-Inyo. It is almost exclusively a trout area, so separations were not made for other fish.

Warm-water fish are also very important in Southern California, which accounted for two-thirds of the 1951 crappie catch, half the sunfish and more than a third of the black bass. Details will be found in Table 15. Under normal rainfall conditions this region ordinarily yields even higher proportions of warm-water fish. (Curtis, 1949).

Almost half of the total abalone were taken in the Southern Region. Other marine sport fisheries not covered by the survey are also of great importance there.

An estimated 415,350 anglers (40.9 percent) live in Region 5.

TABLE 16

Trout Angling in Southern California and Mono-Inyo

	Number of reports	Sub-regional catch		Successful anglers		Mean catch per successful angler
		Total	Percent of State catch	Number in sub-region	Percent of State total	
Mono-Inyo	262	3,690,000	20.6	93,000	19.0	39.5
Southern California	199	1,810,000	10.1	70,000	14.3	25.7

SUMMARY

A survey of 1951 angling in California was made by sending questionnaires to a sample of licensees.

Trout angling has not changed appreciably since 1946. An estimated 429,000 successful trout anglers caught 18,600,000 fish during 1951.

Striped bass angling has also remained quite stable in recent years. An estimated 144,000 successful anglers caught 1,490,000 striped bass in 1951.

Warm-water fisheries have declined recently, probably because of a prolonged drought in Southern California. It is estimated that 108,000 successful anglers took 1,280,000 black bass; 76,000 anglers took 2,380,000 crappie; and 102,000 anglers took 4,800,000 sunfish in 1951.

Catfish angling took a slight upward trend, with 171,000 successful anglers catching 4,710,000 catfish.

The salmon sport fishery showed a large increase in 1951, with 79,000 anglers catching 564,000 salmon.

These data are also analyzed by administrative regions.

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CALIFORNIA MARINE AND FRESH WATER SPORT FISHING INTENSITY IN 1951[1]

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CONTENTS

INTRODUCTION

Increased interest in marine sport fishing has resulted in need for a better understanding of the biology of marine game fishes and of methods for maintaining and if possible improving such fisheries. There have been many statements by marine sports fishermen and marine sports fishermen's organizations that they are not receiving their money's worth when they buy their angler's license because most of the license money is spent on fresh water investigations. Fresh water fishermen, on the other hand, naturally oppose any diversion of such monies from fresh water studies.

In 1948 two types of surveys were made in California to determine where and how the sportsman expends his fishing effort (Calhoun, 1950). One survey was based on a postal card questionnaire sent to a random sample of sport fishermen. Such questionnaires produce about 30 percent usable returns and this raises the point that respondents may have different fishing habits than do nonrespondents. To analyze this possibility, the Opinion Research Center of the University of Denver conducted a personal interview survey. Comparison of these two survey results indicated that respondents and nonrespondents had similar fishing habits and that a postal card survey will give a reliable measure of sport fishing intensity.

The personal interview survey obtained some information about the proportion of the fisherman's time spent in salt water fishing and resulted in an estimate of 25 percent (Opinion Research Center, 1949).

[1] Submitted for publication August, 1952.

Since this was the only figure available it was accepted as the unit for apportioning monies available to California from federal aid to fisheries funds raised from a tax on fishing tackle, usually referred to as Dingell-Johnson funds. Salt water anglers have felt that marine fishing intensity is greater than 25 percent and that the personal interview survey, based on 1,250 interviews, was not a large enough sample to give a reliable measure. Such anglers have urged that every fisherman, when buying a license, fill out a questionnaire which would tell where he fished in the previous year. Such questionnaires have been tried by the California Department of Fish and Game and found impractical because most fishermen buy their licenses through dealers who do not have the time to see that the questions are completely and thoughtfully answered. A postal card mailed to the fisherman can be filled out in his home where he has the time to consider each question and answer as accurately as his memory permits.

To meet the demand for new and more complete information, the Bureau of Marine Fisheries devised a relatively simple postal card questionnaire and mailed it, during April and May, 1952, to approximately 3 percent of all 1951 angling license buyers.

By the end of June this survey resulted in 8633 usable returns and indicated that in 1951 California sports fishermen spent their total fishing days as follows: 32 percent on the ocean and coastal bays, excluding San Francisco Bay and the Sacramento-San Joaquin Delta, 12 percent on San Francisco Bay and Delta, and 56 percent on fresh waters. These results, however, do not necessarily invalidate former surveys. They may merely reflect a rapid upsurge in salt water fishing which has taken place in recent years. Part of this change in fishing interest may have resulted from the recent dry years which impaired fresh water fishing on Southern California inland lakes. Having learned the enjoyment and recreation inherent in salt water fishing, the anglers will, however, continue this activity and pressure on marine waters will presumably continue to increase.

METHOD

Questionnaire Form

The postal card survey, here discussed, was designed to measure fishing intensity in four localities: fresh water, San Francisco Bay and Delta area, ocean and bays north of Santa Barbara, and ocean and bays south of Santa Barbara. Since San Francisco Bay and Delta constitutes a locality which gradually changes from salt to fresh water with no clear cut boundary and supports a type of fishery largely unique to that area, it was treated as a unit distinct from fresh or salt water. Ocean fishing off Northern California differs considerably from that off Southern California and Santa Barbara was chosen as the best well-known division point between these two regions.

The postal card, carrying a stamped self addressed return card, explained that the questionnaire was designed to determine where and how fishing effort was expended in 1951 (Figure 1). The return card asked that the recipient estimate, as accurately as possible, the number of days he spent fishing in each of the areas.

Will You Help Improve Fishing in California?

California faces the problem of deciding how much of the money available for sport fish studies should be spent on fresh water projects and how much on salt water. A wise decision depends on knowing how much time anglers spend fishing in fresh and in salt water.

The California Department of Fish and Game is attempting to get this information by asking a selected number of anglers where they fished in 1951. You are one of them. You can help by filling in the squares on the return card as accurately as you can. Be sure to include in your total the number of days you dug for shellfish and also the number of days on which you fished but caught nothing.

You do not need to sign the card for this is not a personal check-up, but please return it and help us determine how the money you contribute should best be spent.

CALIFORNIA DEPARTMENT OF FISH AND GAME

56379 1 52 30M SPO

Please help the California Department of Fish and Game in its efforts to improve fishing by filling out and mailing this card.

How many days in 1951 did you fish or gather shellfish in California? Include the days on which you caught nothing.

Number of days

FRESH WATER . . . . [ ]

SALT WATER

San Francisco Bay and Delta . . . . [ ]

Ocean and other bays
North of Santa Barbara . . . . [ ]

South of Santa Barbara . . . . [ ]

FIGURE 1. Postal card questionnaire used in the 1951 survey

Selection of Sample

Surveys made by the Bureau of Fish Conservation (Calhoun, 1950, 1951) have indicated that a sample of 1,000-2,000 respondents will give reliable measures of fishing effort. Because the present survey was planned not only to measure fishing intensity on fresh and salt water but also to measure intensity in the three salt water areas, a sample large enough to yield about 2,000 returns from marine fishermen was needed. The former surveys indicated that 25 percent of fishing effort would be expended in marine fishing and it was estimated that 8,000 returns would be required. Other surveys also demonstrated that about one third of the recipients of cards would respond. Based on these two figures a

sample of about 30,000 cards was planned. California license sales in 1951 totaled approximately 1,000,000 and to select a random sample of 30,000 it was necessary to send the questionnaire to three out of every 100 license buyers.

In 1951 California had four types of sport fishing licenses: an annual $3 license sold to residents of California, a $3 license good for ten days sold to fishermen who were not California residents, a $10 annual license sold to fishermen who were not California residents, and a $25 annual license sold to fishermen who were not United States citizens. Children under 16 years do not need a license and, therefore, are not included in this survey.

The $3 annual licenses are bound in books of 25. On the stub of each license, which remains in the book, is recorded the name and address of each license buyer. To obtain a random sample of three from each 100 of these licenses, four books were picked at random and the third stub from each of the first three books was selected as the recipient of the questionnaire. No selection was made from the fourth book. This process was continued until all $3 license books issued throughout the entire State had been used. License stubs for the remaining three types of licenses were grouped at random in lots of 100 and the thirty-third, sixty-sixth and ninety-ninth stub selected. For all licenses, if the tenth stub bore a nonlegible or incomplete address, the first following complete stub was substituted. This method of selecting recipients resulted in mailing out 29,464 postal cards. Mailing was begun in March, 1952, and completed by April 20.

FISHING INTENSITY

Total Returns

By June 20, 1952, a total of 9,168 cards had been returned and the survey was terminated. This sum, 31 percent of the total mailed, comprised 8,633 usable cards, or 29 percent, 181 from respondents who

TABLE 1

Returns From Cards Used in the 1951 Survey

	Resident citizen $3	Type of license: Nonresident 10-day $3	Nonresident Annual $10	Non-citizen annual $25	Total Number	Total Percent
Mailed	29,098	264	70	32	29,464	
Returned						
Unclaimed	266	2	----	----	268	0.91
Deceased	5	----	----	----	5	0.02
Not usable	79	2	----	----	81	0.27
No fishing	176	3	2	----	181	0.61
Usable	8,523	82	22	6	8,633	29.30
Total returned	9,049	89	24	6	9,168	----
Percent returned	31.10	33.71	34.29	18.75	31.12	----

bought licenses but did not fish, 81 from persons who replied but did not give complete information, five returned by relatives stating the recipient had died during the year, and 268 returned by the post office because the recipient had moved with no forwarding address or could not be located at the address given (Table 1).

Intensity by Area

Respondents who returned the 8,633 usable cards reported a total of 218,963 fishing days. Of these, 56 percent was spent fishing in fresh water, 12 percent in San Francisco Bay and Delta, 10 percent in the ocean and bays north of Santa Barbara and 22 percent in the ocean and bays south of Santa Barbara (Table 2).[2] Thus 32 percent of the 1951 fishing effort was on California's ocean and coastal bays and 56 percent on her fresh waters. The 12 percent of fishing time spent on San Francisco Bay and Delta cannot be classified as either fresh or salt water

[2] The standard errors of these percentages were calculated from the formula

$$SE = \sqrt{p \times q \times n},$$

where p is the ratio of fishing days, q the ratio of no fishing days and n the total of all fishing days.

TABLE 2

Distribution of Fishing Intensity Based on 8,633 Usable Returns

Fishing area	Number reporting[1]	Fishing days		Standard error	Total fishing days	Average days per fisherman
		Number	Percent			
Fresh water						
Resident citizen	6,711	121,956				
10-day nonresident	56	288				
Annual nonresident	22	112				
Noncitizen	6	116				
Totals	6,798	122,772	56.07	0.11	14,221,000	18.06
San Francisco Bay and Delta						
Resident citizen	1,875	26,537				
10-day nonresident	7	11				
Annual nonresident	2	2				
Noncitizen	1	6				
Totals	1,885	26,556	12.13	0.07	3,077,000	11.09
Ocean and Bays North of Santa Barbara						
Resident citizen	2,151	22,283				
10-day nonresident	15	10				
Annual nonresident	1	1				
Noncitizen	2	54				
Totals	2,169	22,378	10.22	0.06	2,592,000	10.32
Ocean and Bays South of Santa Barbara						
Resident citizen	2,996	47,118				
10-day nonresident	18	46				
Annual nonresident	2	93				
Noncitizen						
Totals	3,016	47,257	21.58	0.09	5,473,000	15.67
Grand totals	8,633	218,963	100.00		25,363,000[2]	25.363[2]

[1] The sum of these numbers exceeds 8,633 because many fishermen reported fishing in more than one area.
[2] 218,963/8,633 = 25.363 × 1,000,000 licenses = 25,363,000.

and should be considered as a distinct and special type of fishing, catching mainly anadromous fish, salmon and striped bass, but including some catfish, perch and smelt.

Since the chief object of this survey was to determine proper allocation of revenue, consideration should be given to the value of the license. To do this the number of fishing days per license type for each area was weighted by the value of the license and new percentages calculated. The results differed from the unweighted percentages by 0.1 percent or less and the unweighted values are used throughout this report. The number of $3 licenses far exceeds all other types and determines where and how fishing effort will be expended and what will be the total income from license sales.

The average number of days per fisherman in fresh water was 18, in San Francisco Bay and Delta 14, in northern ocean and bays 10, in southern ocean and bays 16, and the average for all types 25. The average for all types exceeds any one area because many fishermen fished in more than one region. This average multiplied by 1,000,000 [3] licenses gave over 25,000,000 fishing days in all California waters in 1951.

Comparison With Other Measures

Calhoun (1950) calculated the average number of days per fisherman and the total number of fishing days for the three war years, 1941-43, and for 1946 and 1948. For 1941 through 1946 the average days per fisherman varied from 13 to 14 and for 1948 increased to 15.4 but dropped to 13 in 1949 (personal communication). Calhoun (1953, Table 1) also made a survey in 1951 and again had an average of 15 days. These figures are considerably less than the 25-day average obtained in this survey.

[3] License sales in 1951 totaled approximately 1,015,250 but the rounded figure of 1,000,000 has been used in these calculations, and obviates a correction for license buyers who did not fish. This small percentage of licenses is not included in any of the calculations of average days per fisherman.

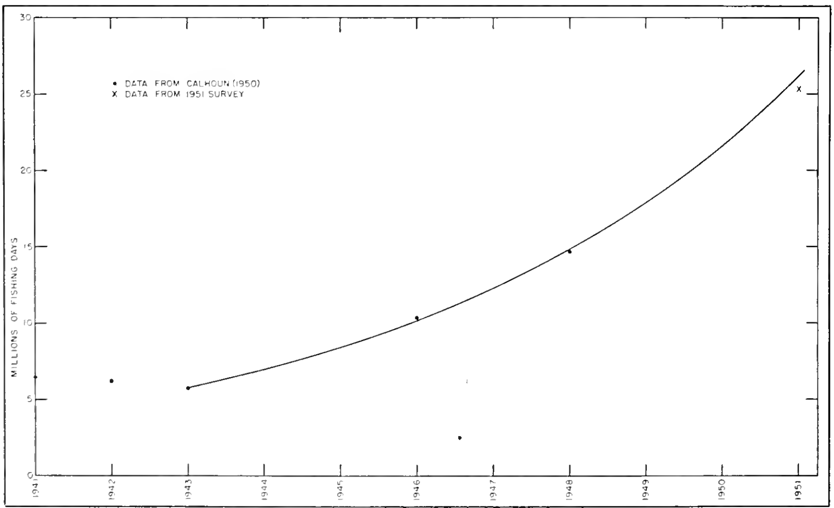

FIGURE 2. Total fishing days in California waters from Calhoun (1950) and from 1951 survey. Line fitted to Calhoun data by least squares.

Such differences have a material effect on the measures of total fishing intensity and the reason for the discrepancy is not apparent.

During the war years the number of license sales and average fishing days remained relatively constant and the product of these two figures gave a total of approximately 6,000,000 fishing days. In 1946 increased license sales brought the total up to 10,000,000 and additional license sales with an increase to 15 average days per fisherman brought the 1948 total to 15,000,000 days. A trend line fitted to Calhoun's data for 1943, 1946 and 1948 and extrapolated to 1951 gives a value of 26,110,000 fishing days for the 1951 season (Figure 2). This is remarkably close to the 25,363,000 obtained from this 1951 survey (Table 1) based on an average of 25.363 days per fisherman. The total license sales have shown little increase in the last three or four years, however, and this 25,000,000 total is dependent on the increase in average days per fisherman; not on greater license sales. If Calhoun's average of 15 days were used the total would be 15,000,000 and no greater than in 1948.

Perhaps our questionnaire asking the respondent to list the number of fishing days by area resulted in a more careful enumeration of his fishing effort or it may have tended toward exaggeration. Calhoun's questionnaire, on the other hand, may have resulted in an understatement. Presumably the true value lies somewhere between 15 and 25 days per fisherman and present sport fishing pressure on California's fresh and salt water fishery resources is between 15 and 25 million man-days per year.

Comparison With Smaller Samples

To send out and tabulate the returns from 30,000 postal cards is an expensive and time consuming undertaking. To determine what percentages would have been obtained if a smaller sample had been used, all usable returns were thoroughly mixed and five random samples of 1,000 cards each were drawn and tabulated. The results (Table 3) gave percentages for any fishing area which did not differ by more than 2.5 percent from the total sample. The sum of the five samples yielded percentages within less than 0.3 percent of the total values.

The greatest difference between the average number of fishing days for each of the 1,000-card samples and the total average was 1.5 days. Calculations of the total number of fishing days differed, therefore, by about $1\frac{1}{2}$ million and for any given area from 100,000 to 800,000. Statistical tests of the differences in the percentage and total fishing day values indicated significance [4] and the differences cannot be attributed to chance sampling errors. For practical purposes, however, such minor variations are of little importance and the test shows that returns of 1,000-2,000 cards would give sufficiently accurate information to estimate fishing intensity and localities of greatest fishing pressure.

Number of Fishermen per Area

Although the number of fishing days expended in each fishing area is of major importance in determining allocation of funds, it is also of interest to know fishermen preferences. For the five samples of 1,000 cards, records were compiled of the number of fishermen reporting fishing in one area or in any combination of more than one area. There are 15 different classifications in this type of tabulation (Table 4).

[4] p values of less than .01 by chi square tests.

TABLE 3

Comparison of 8,633 Returns With Five Samples of 1,000 Returns

Area	8,633 Returns	Samples of 1,000 returns					5,000 Returns
Percentage of fishing days in each area							
Fresh water	56.07	55.79	58.06	55.47	56.29	54.77	56.06
Difference		—.28	+1.99	—.60	+.22	—1.30	—.01
San Francisco Bay and Delta	12.13	11.74	11.20	10.71	11.74	14.03	11.89
Difference		—.39	—.93	—1.42	—.39	+1.90	—.24
Ocean and Bays north of Santa Barbara	10.22	8.37	9.87	10.20	10.39	12.14	10.21
Difference		—1.85	—.35	—.02	+.17	+1.92	—.01
Ocean and Bays south of Santa Barbara	21.58	24.10	20.86	23.62	21.58	19.06	21.84
Difference		+2.52	—.72	+2.04	0	—2.52	+.26
Average days per fisherman	25.36	24.92	25.06	26.43	23.86	26.12	25.28
Difference		—.44	—.30	+1.07	—1.50	+.76	—.08
Number of fishing days in each area							
Fresh water	14,200,000	13,900,000	14,500,000	14,700,000	13,400,000	14,300,000	14,200,000
Difference		—300,000	+300,000	+500,000	—800,000	+100,000	0
San Francisco Bay and Delta	3,100,000	2,900,000	2,800,000	2,800,000	2,800,000	3,700,000	3,000,000
Difference		—200,000	—300,000	—300,000	—300,000	+600,000	—100,000
Ocean and bays north of Santa Barbara	2,600,000	2,100,000	2,500,000	2,700,000	2,500,000	3,200,000	2,600,000
Difference		—500,000	—100,000	+100,000	—100,000	+600,000	0
Ocean and bays south of Santa Barbara	5,500,000	6,000,000	5,200,000	6,200,000	5,100,000	5,000,000	5,500,000
Difference		+500,000	—300,000	+700,000	—400,000	—500,000	0
Totals	25,400,000	24,900,000	25,000,000	26,400,000	23,800,000	26,200,000	25,300,000
Difference		—500,000	—400,000	+1,000,000	—1,600,000	+800,000	—100,000

TABLE 4

Number of Fishermen Fishing in Various Areas—Based on 5,000 Returns

	Samples of 1,000 returns					Total	Percent
Fresh water only	334	363	319	337	285	1,638	32.76
San Francisco Bay and Delta only	32	26	22	36	34	150	3.00
Ocean and Bays north of Santa Barbara only	32	39	37	35	37	180	3.60
Ocean and Bays south of Santa Barbara only	116	110	116	120	108	570	11.40
Fresh water and San Francisco Bay and Delta	50	60	80	70	81	341	6.82
Fresh water, ocean and bays north of Santa Barbara	81	90	95	83	105	454	9.08
Fresh water, ocean and bays south of Santa Barbara	218	200	178	[illegible]	[illegible]	960	19.20
San Francisco Bay and Delta, ocean and bays north of Santa Barbara	23	17	18	19	[illegible]	100	2.00
San Francisco Bay and Delta, ocean and bays south of Santa Barbara		4	2	2		[illegible]	[illegible]
Ocean and Bays north and south of Santa Barbara	10	5	7	8	[illegible]	40	.80
Fresh water, San Francisco Bay and Delta, ocean and bays north of Santa Barbara	61	54	66	72	57	[illegible]	7.00
Fresh water, San Francisco Bay and Delta, ocean and bays south of Santa Barbara	11	7	13	7	7	45	.90
San Francisco Bay and Delta, ocean and bays north and south of Santa Barbara	2	4	[illegible]		2	12	.24
Fresh water, Ocean and Bays north and south of Santa Barbara	18	10	[illegible]	24	[illegible]	102	2.04
Fresh water, San Francisco Bay and Delta, ocean and bays north and south of Santa Barbara	12	[illegible]	[illegible]		8	[illegible]	[illegible]
Totals	1,000	1,000	1,000	1,000	1,000	5,000	100.00

TABLE 5

Number and Percentage of Fishermen Fishing in Combined Areas—Based on the 5,000 Sample

	Number	Percent
Fishing In:		
Fresh water only	1,638	32.76
Fresh water and all other areas	2,301	46.02
Total fresh water	3,939	78.78
Ocean only	790	15.80
Ocean and all other areas	2,081	41.62
Total ocean	2,871	57.42
San Francisco Bay and Delta only	150	3.00
Bay and Delta and all other areas	906	18.12
Total San Francisco Bay and Delta	1,056	21.12

Of the 5,000 fishermen, 33 percent reported fishing in fresh water only, 3 percent in San Francisco Bay and Delta only, 4 percent in the northern ocean and bays only, and 11 percent in the southern ocean and bays only. The second highest percentage, 19, was reported by fishermen fishing in fresh water and in ocean and bays south of Santa Barbara. Slightly less than 1 percent reported fishing in all four of the areas. Approximately a third of California anglers fish only in fresh water and about one-sixth in ocean waters only. Nearly half of the fishermen are more versatile in their interests and fish in two or more types of waters.

This diversity of interest is somewhat clarified in Table 5. In this table the numbers and percentages of fishermen fishing in only one of the three major areas or in that area and all other areas are summarized. The tabulations show that 33 percent of the fishermen fished in fresh water only and 46 percent in fresh water and in one or more of the other areas; 16 percent fished in the ocean only and 42 percent in the ocean and one or more of the other areas; 3 percent in San Francisco Bay and Delta only and 18 percent in the Bay and Delta and one or more of the other areas.

SUMMARY

The 1951 postal card survey was designed to measure the sport fishing effort in four areas.

From the 29,464 cards mailed, 8,633 usable returns (29 percent) were received. Of the total number of fishing days reported, 56 percent was spent on fresh waters, 12 percent in the San Francisco Bay and Delta area, 10 percent on the ocean and bays north of Santa Barbara and 22 percent on the ocean and bays south of Santa Barbara.

The average number of days per fisherman was 25, for a total of approximately 25,000,000 fishing days on California waters in 1951. Of these, 14,000,000 were spent on fresh waters and 8,000,000 on the ocean and bays excepting San Francisco Bay. In the San Francisco Bay and Delta area fisherman spent 3,000,000 fishing days.

Thirty-three percent of the fishermen reported fishing in fresh water only, 3 percent in San Francisco Bay and Delta only and 16 percent in the ocean and other bays only.

Samples of 1,000 cards gave practically the same results as did the 8,633 cards.

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FOOD OF MARLIN IN 1951 OFF SAN DIEGO, CALIFORNIA[1]

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The unusual numbers of marlin, *Makaira mitsukurii* (Jordan and Snyder) that were taken by anglers off San Diego in 1950 and 1951[2] provided an opportunity for the determination of its food and other characteristics. Advantage was not taken of this opportunity until late in the 1951 season, when the stomachs of 32 specimens were obtained through the cooperation of Mr. Luther H. Barber, Jr., of the Frosty Freezer in La Jolla and of S. Howard Minor, Jr. and the H and M Sportfishers of San Diego. A. A. Allanson assisted in the procurement of the material.

The marlins were all caught on sport gear near San Diego. All or nearly all came from an arc extending from a few miles west of Point Loma to about five miles southwest of Los Coronados Islands. They were medium-sized adults in the striped phase or of the striped species (we are inclined to the belief that "black marlin" are the older, but not always larger adults of the same species, with thicker bodies and relatively smaller fins and beaks, comparable to the pudgy, dark, unspotted, short-finned adults of the channel catfish, *Ictalurus punctatus* (Rafinesque), that long rated specific recognition—see Hubbs and Allen, 1943, p. 118). The marlin weighed on the average 135 to 140 pounds. One each was caught on August 20 and August 21, 1951; most or all of the others, from October 1 to 26, 1951.

The minimal numbers of individuals of each food item were estimated, usually from counts of the tail ends, which are most persistent. The volumes were roughly measured by water displacement in graduate cylinders. There were rather large sources of error in all these determinations and only close approximations were attempted. Even the rough quantifications, however, are regarded as superior to mere guesswork or verbal statements from visual comparisons. No attempt was made to reconstruct the volumes of largely digested specimens.

Except for small fragments of flesh the food remains, with few exceptions, were identified with little doubt. Clothier's 1950 contribution on the vertebral characters of Southern California fishes was particularly helpful. Incomplete and largely defleshed skeletons were recognized by comparison with the corresponding parts, laid bare, of more complete, readily identifiable remains.

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[1] Contributions from the Scripps Institution of Oceanography, New Series, No. 601. Submitted for publication July, 1952.

[2] S. Howard Minor, Jr., who keeps the local marlin records, reports that at least 585 were caught in 1950 and at least 381 in 1951, in the area from off La Jolla to about Los Coronados Islands.

In both numbers of individuals eaten (907) and volume of food remains (14,656 cc.) the saury, *Cololabis saira* (Brevoort) vastly predominated (Table 1), just as it did in the food of albacore, *Germo alalunga* (Gmelin) of the Pacific Coast, as recently reported by McHugh (1952). The albacore examined by McHugh, however, fed on sauries to the extent of only 30 percent during the period when we find sauries comprising about 75 percent of the food of marlin. The sauries may have been eaten so predominantly merely because they are the most abundant fish of appropriate size in the area just off the close-inshore waters of Southern California.

Had the marlin stayed closer to the shore, northern anchovies, *Engraulis mordax* (Girard), might well have formed the bulk of the food. One marlin, caught rather close to shore, 9 miles southwest of Point Loma on August 20, contained more than half (1,395 cc.) of the total volume of anchovy remains removed from all 32 stomachs (in addition, this fish contained only one saury head, measuring 2 cc.). The northern

TABLE 1

Food Contents of 32 Marlin Caught Near San Diego in 1951

Species of food[1]	Estimated number			Volume of remains, cc.		
	Total	Ave. per marlin	Percent of fish food	Total	Ave. per marlin	Percent of fish food
Saury	907	28.3	75.5	14,656	458	72.4
Northern anchovy	249	7.8	20.7	2,362	74	11.7
Pacific sardine	21	0.7	1.7	1,742	54	8.6
Jack mackerel	20	0.6	1.7	591	18	2.9
Pacific mackerel	2	0.1	0.2	153	5	0.8
Halfmoon	1	trace	0.1	6	trace	trace
Bonito (?)	1	trace	0.1	trace	trace	trace
Unidentified fish fragments	?	?	?	745	23	3.7
Total fish	1,201+	37.5	100	20,255+	633	100
Squid	3–6	0.9–1.9	----	trace	trace	----

[1] For scientific names, see text.

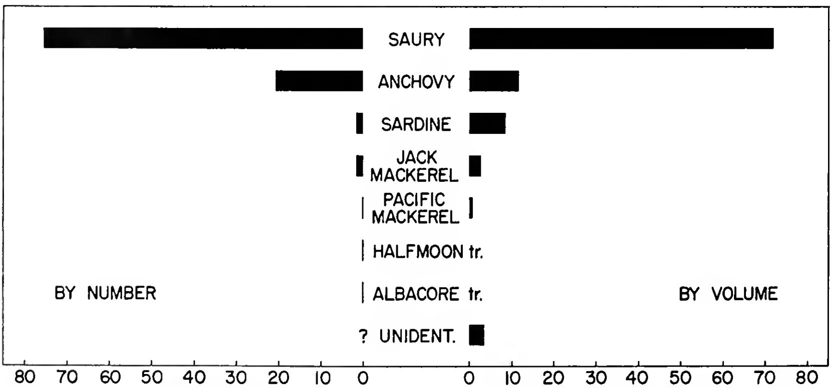

FIGURE 1. Percentage composition of fish food of 32 marlin

anchovy was definitely second in numbers (219, or about 21 percent of the fish eaten) and volume (2,362 cc., or about 12 percent).

Sardines, *Sardinops caerulea* (Girard), and jack mackerel, *Trachurus symmetricus* (Ayres), followed and were close in numbers (respectively 21 and 20), but the large sardines, which were mostly fresh and whole, much exceeded the more digested jack mackerel in volume (1,742 cc. versus 591 cc.). Two partly digested Pacific mackerel measured 153 cc. A large young halfmoon, about half complete, measured 6 cc. (young halfmoons long retain a surface-pelagic habitat). A single bone, a post temporal, almost surely represented a small tuna or tuna like fish, definitely not an albacore, almost surely a California bonito, *Sarda lineolata* (Girard), about one foot long.

The only other recognizable food item comprised six squid beaks, representing three to six individuals of at least two species.

In 19 stomachs of marlin caught during the first week of October, the percentage of stomachs containing each recognizable food item was:

Saury, 95 percent	Anchovy, 32 percent
Sardine, 37 percent	Jack Mackerel, 11 percent
Halfmoon, 5 percent	

It is clear from this examination that the striped marlin feeds on fish of moderate size. Except for the one young halfmoon, *Medialuna californiensis* (Steindachner)—a deep-bodied fish—and the single small bonito, all fish that had been eaten by the marlin examined were half-grown to adult specimens of medium-sized species. No fish eaten, so far as could be determined, was less than three inches long. No trace was seen of larvae or very young juveniles. In this regard the striped marlin seems to contrast sharply with tuna, including albacore (McHugh, 1952). Nor were any of the fish eaten more than about one foot long. It is known, however, that large marlin are capable of eating large tuna, at least those caught on a line (June, 1951).

None of the fish eaten showed obvious signs of having been impaled, cut in two, slashed, or otherwise injured by the marlin's sword, though the marlins, like the swordfish, are said to stun their prey by striking or impaling them with their sword (Norman, 1938, p. 160; Gudger, 1940, p. 225).

No flyingfish were included in the food examined, though *Cypselurus californicus* (Cooper) was common in the region at the time the marlin were caught. Nor were any found in the marlin stomachs analyzed by Wallace and Wallace (1942) and by Morrow (1952). Flyingfish, however, are a favored bait for marlin and were listed as one of their food items by Norman (1938, p. 160).

Very similar results were obtained by Wallace and Wallace (1942) in the study of the food of the "white marlin, *Tetrapturus albidus* Poey" off Maryland and by Morrow (1952) in his work on the food of *M. mitsukurii* in New Zealand. Both found fishes predominating over squid, the only other food item of consequence. In the fish from Maryland, where sauries are rare or absent, the round herring, *Etrumeus sadina* (Mitchill) predominated. (In southern California the local round herring, *Etrumeus othonops* (Eigenmann) is extremely rare.) In New Zealand the local saury, identified by Morrow as *Scomberesox saurus* (Walbaum),

constituted 74.1 percent of the food analyzed by number of individuals of all species eaten. We are grateful to James E. Morrow, Jr., of Yale University, for a copy of his paper, in press at the time of writing.

We find very little published information on the food of marlins. LaMonte and Marcy (1941, p. 18) wrote:

> Our examination of the stomach contents of Marlins has shown that their diet is much the same as that of the Swordfish. Where smaller fishes are plentiful, they are utilized as food; in Chile, where squid are plentiful, the Marlin and Swordfish stomachs were always full of partially digested squid.

And of the swordfish, *Xiphias gladius* Linnaeus, the same authors wrote (p. 7):

> The Swordfish feeds on smaller fishes, such as herring, mackerel, etc., and on squid. The absence or presence of the food supply, and, in turn, the absence or presence of the food supply of the herring, mackerel, etc., largely accounts for the variability in the runs from year to year.

Miss Francesca LaMonte of the American Museum of Natural History and the International Game Fish Association kindly provides some additional items on the food of marlins, as follows:

> In the striped marlins (*M. mitsukurii*) and also in the swordfish (*Xiphias*) I examined in Peru and Chile in 1940, there were only squid in the stomachs. Squid are thick there from surface to several feet down at night and evidently the marlins and swordfish had fed on them at night because those taken in the morning showed less digested squid than those taken in late afternoon, when usually only beaks and eyes were left. We got no blacks there that year.
>
> Dr. D. G. Maitland of Sydney, Australia, has recently written us as follows: "It may interest you to know that I have actually watched a pair of Black Marlin feeding upon Physalia—like huge Rainbow Trout taking flies, and absolutely ignoring a most tempting looking mackerel bait drifting in front of their noses."
>
> In notes from Bimini for blue marlin, I find that a blue weighing 420 lbs. caught July 8, 1937, had in its stomach a bonito weighing 5½ lbs. The bonito was doubled in the stomach, tail to head and practically whole; only its belly was opened a little. Nothing else was in the marlin's stomach.
>
> In several blues caught in 1949 and 1950 off Bimini there were small *Scomberomorus* partially digested; in one the skull and bones of a small grunt; in one some squid and a few fish bones; in one an almost undigested *Caranx latus* about 15″ long, and in one the bait—a bonefish.
>
> In Acapulco, Mexico, most of the few specimens taken of black, striped, and "silver" marlins had thrown the stomach contents; in all others, the contents were absolutely liquid and could not be identified.
>
> In no case have I ever seen anything that seemed to have been slashed by the spear or impaled upon it.

Our study suggests that the striped marlin in California feeds chiefly on the saury, a species that is seldom utilized here by fishermen. A few sauries have been experimentally packed at Monterey (in the scarcity of sardines), but there is no regular fishery in California for this abundant species, as there is in Japan. The other species that we find to be eaten by marlin near San Diego are all caught in the sport, commercial, or bait fisheries. The marlin is so highly prized, however, that no great concern will likely be felt over the fish it consumes or over its competition for food with other commercial or game fishes. It is highly improbable that enough marlin visit our coast, even in seasons of greatest abundance, to make any serious inroads on the numbers of the species that it feeds upon.

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AN UNUSUAL MORTALITY OF CALIFORNIA YELLOWTAIL *(SERIOLA DORSALIS)* IN A MARINE AQUARIUM[1]

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Sometime between the hours of 9 p.m. June 18th and 7 a.m. June 19 1952, an unusual phenomenon resulted in the death of all the California yellowtail held in captivity at the marine aquarium of the Scripps Institution of Oceanography, La Jolla, California. The 11 fish had been in captivity for several months as an experiment by the California Department of Fish and Game to investigate various types of fish tagging material. The only other animals in the tank were four sea turtles. The fish were maintained in a 2,500-gallon aquarium tank provided with aeration and constant running sea water collected from the Scripps pier. The water entered the tank from one end at an average flow of approximately 150 gallons per hour. Although it is difficult to calculate the water exchange, it is estimated that a complete change would require from two to three days. The prevailing temperature of the aquarium water at the time of the incident was approximately 17 degrees C. or that of the adjacent ocean water.

On June 18th the yellowtail, apparently in a healthy condition, were fed their semiweekly rations of beef liver which had been thawed from the frozen state. Although the same food was provided to the animals in several of the other aquaria, the yellowtail tank at this time, contrary to usual procedure, was supplied with an excess of beef liver in an attempt to induce the sea turtles to eat. As a result a considerable amount of liver residue was left in the tank, both in fine suspension and in larger pieces on the bottom. At 9 o'clock that night the aquarium curator made his rounds and reported that the fish were apparently in a healthy condition and had a normal appearance.

On the morning following their feeding all the fish were found lying dead at the bottom of the tank, while the four sea turtles were still alive. The water appeared somewhat cloudy and there was a considerable amount of decomposing residue at the bottom of the tank. While the fish were being removed from the tank, much more debris was noticed on the bottom of the tank than could be accounted for by the overfeeding of the fish the previous day. The outward appearance of the fish was normal except that the skin was covered with a heavy mucous coat which was thick and white in appearance with small dark granules. Dissection of the fish revealed a normal appearance of the internal organs except for the fact that the stomachs contained no food. Therefore it was concluded that the fish had regurgitated most or all of the food that had been

[1] Contribution from the Scripps Institution of Oceanography, New Series N. 597. Submitted for publication August, 1952.

eaten the previous day. Any remaining food in the stomachs had been digested during the interim. Checking over the history of the fish it was noted that regurgitation had occurred before at infrequent intervals during their captivity.

Parts of the slime were removed and taken into the laboratory, where they were examined in wet preparation by phase microscopy. The examination showed an oily substance which contained innumerable bacteria of various types. The predominating type appeared to be a rather plump rod approximately one and a half by three microns in length. Many of the bacteria were highly motile, and to all outward appearances the slime was literally filled with bacteria. Phase microscopic examinations were also made of various other parts of the fish and of the water in the aquarium tank. The results of these examinations showed that the aquarium water contained approximately 10 million bacteria per ml which is considered a very heavy concentration. An unusual quantity of mucus had gathered on the surfaces of the gills rendering them somewhat opaque and with only a slightly pinkish tinge instead of the normal bright color. There were many bacteria present on the gill surfaces. Also small rod and coccus types of bacteria were seen among the red and white cells of the blood.

On the same date the other aquaria were examined for bacteria and for their outward appearance. It was noted that all were fairly clear except for one tank which contained the elasmobranchs. A bacteriological examination of the water in these tanks showed the normal numbers of bacteria. A conference with the aquarium maintenance men indicated that the normal flow of water had continued throughout the night. This report was supported by the fact that the water in the aquarium containing the yellowtail had the same temperature as that in the other aquaria. In the other aquaria the fish were all in an apparently normal, healthy condition.

Considering the very rapid and approximately simultaneous death of the yellowtail, it seems improbable that the cause was a specific bacterial or virus disease. There were no outward lesions on the fish and there was no evidence that the fish had struck themselves against the aquarium walls. The animals were apparently normal except for the mucus covering their outer surface and the lack of food in their stomachs.

As no previous mortality of this nature is known to the author, a conclusion as to the cause of the present phenomenon cannot be based on former experiences. However, it is possible to derive a set of tentative conclusions based upon the results obtained by visual and microscopical examinations.

It is well known that beef liver provides an excellent medium for the growth of many bacteria. Therefore, the knowledge that the fish had been overfed the day previous to their death leaving excess liver in the tank would suggest that conditions may have strongly favored the growth of bacteria. This feature, combined with the elevated temperature, would augment the conditions favorable to bacterial growth. Bacteria present in large enough concentration to cause an irritation to the intestinal tract of the fish may have initiated the regurgitation. Acting to increase the supply of readily available organic material in the water of the aquarium, the regurgitated matter would provide a still better medium of growth for bacteria. This may well have accounted for the extremely

large number of 10 million bacteria per ml as demonstrated the following morning.

It is assumed that the increased number of bacteria may have accelerated the production of the protective slime over the surface and on the gills of the fish. As this happened the oxygen-absorbing properties of the gills would become reduced and at the same time the numbers of bacteria in the tank, increasing to a point where they could utilize most of the available oxygen in the water, would create partially anaerobic conditions. The observed absence of hydrogen sulfide gas eliminated the possibilities of poisoning by this substance in an anaerobic environment. Combined with the tendency of the mucus to exclude oxygen from the gills, the conditions could certainly cause asphyxiation. One might support these conclusions by the knowledge that bacteria were found in the blood stream of the fish after death. This could conceivably have occurred by the increased numbers of bacteria on the surface of the gills actually penetrating into the small capillaries and invading the blood stream itself while the fish were still living. It seems questionable whether the bacteria were in large enough concentrations in the blood to have been directly responsible for the fatalities.

THE EFFECT OF CHANNELIZATION ON THE FISHERY OF THE LOWER COLORADO RIVER[1]

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During the period of 1936 to 1938, Hoover, Parker, and Imperial Dams were completed on the lower Colorado River. As a result, rapid changes in the ecology of the river, expansion of the game fish populations, and subsequent establishment of valuable sport fisheries took place. Dill (1944) described the characteristics of this river-reservoir system as it existed in 1942, and both he and Stevens (1938) predicted some of the ultimate changes.

Since that time many alterations in the ecology, both natural and man-made, have occurred in these waters. This report is concerned with the man-made changes brought about by river channelization.

Under Public Law 469, June 28, 1946, the Bureau of Reclamation is authorized to carry out a program of "controlling the Colorado River and modifying, straightening and rectifying the channel thereof." In short, this means river channel dredging. To date the Bureau of Reclamation has dredged the river from Needles to Topock, has also dredged a section of the river in the Palo Verde area, is now in the process of dredging from Needles to Davis Dam, and has completed its plans for extensive operations in the Lake Cibola area. It is a distinct possibility that the entire channel from Headgate Rock Dam downstream to Imperial Reservoir will eventually be dredged. The undesirable effect of dredging on the fishery in the Needles-Topock section is a preview of what may be expected to result from operations in other portions of the river.

Prior to this channelization, there existed at the lower end of Mohave Valley, between the towns of Needles and Topock, a large marsh containing many lakes and sloughs, through which the Colorado River meandered. The total area of still water maintaining fish populations was estimated at 4,300 surface acres. In addition, the main channel of the river supported a healthy population of fishes (see Dill, 1944, for a complete list). Largemouth black bass (*Micropterus salmoides*), bluegill (*Lepomis macrochirus*), and black crappie (*Pomoxis nigromaculatus*) predominated in the lake environment, while channel catfish (*Ictalurus punctatus*) and to a lesser extent largemouth bass supported the fishery in the river habitat. Although no creel census data were obtained, fishing quality was known to be high. The U. S. Fish and Wildlife Service, Office of River Basin Studies, Region 2, carried out field investigations in 1948-49 and estimated the annual fishery recreation value at $37,800. This figure is derived from a curve based on the area of fishable water,

[1] Submitted for publication September, 1952. Based in part on data collected by the U. S. Fish and Wildlife Service, Office of River Basin Studies, Region 2.

type of fishery, and value of similar types of lakes and streams throughout the United States. It was estimated that the California river bank in the project area received a use of 1,200 fisherman-days per mile per year. While the California Department of Fish and Game does not use the same system of evaluation, these figures do give some indication of the value of the fishery.

In 1951 the Bureau of Reclamation completed a program of channel dredging and marsh drainage in this area, purportedly for flood protection for the Town of Needles and the reduction of water losses through

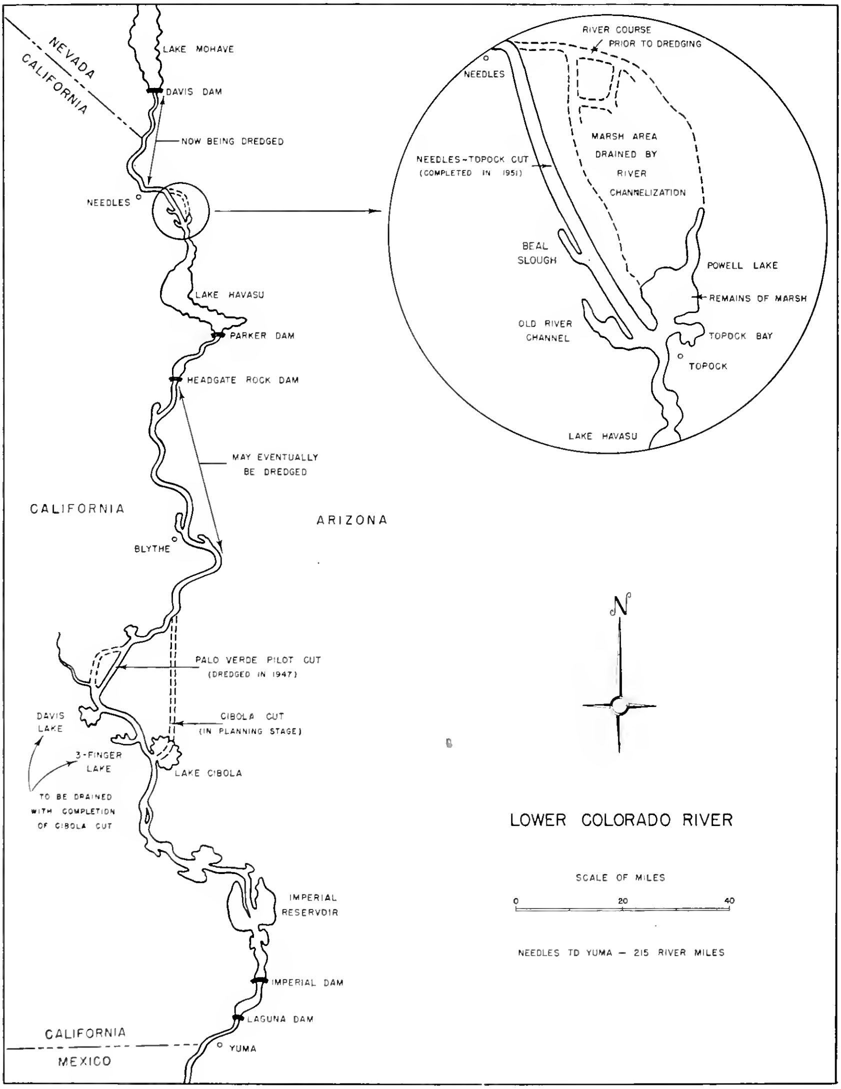

FIGURE 1. The lower Colorado River bordering the State of California. A sketch showing the sections of the river that have been, or will be, channelized.

evaporation. This project confined the full flow of the river to a newly dredged channel extending from Needles 10 miles south to Topock. This channel is 17 feet in depth, 250 feet in width, and is designed to carry 75,000 second-feet of water at maximum capacity. It has a slope of two feet per mile. A levee borders its Arizona side and effectively seals off the adjoining lakes and sloughs from the river.

The project has drained a large percentage of the lake and slough habitat that supported most of the fishery. The main channel has been changed from a meandering stream containing many eddies and "holes" productive of fish life to a straight dredged sluice whose waters are high in turbidity and lacking in cover and food.

Wherever an adjoining backwater has been drained the loss in fishery value has been 100 percent. The changes to the river channel as a result of dredging are not so easily measured. However, it is believed that the damages to the river habitat in terms of fishery value are quite severe. The Fish and Wildlife Service estimated the present fishery to be valued annually at approximately $5,600. This represents a loss of $32,200 worth of sport fishery per year.

At the present time but few fishable waters remain on the California side of the river. Two backwaters, Beal Slough and the old river channel, totaling 76 surface acres, lie west of and join the dredged channel.

Remaining on the Arizona side are limited areas of still water at Powell Lake and Topock Bay. An opening in the dike bordering the east side of the channel allows water to back up into a portion of the former marsh.

At the present time the Fish and Wildlife Service is planning a marsh rehabilitation project on the Arizona side; it will consist of a headgate and dike system to reflood a portion of the marsh lost as a result of the dredging. This project is primarily concerned with waterfowl development, but waters suitable for the production of game fishes will be maintained where applicable.

CONCLUSIONS AND RECOMMENDATIONS

River channel dredging has decreased the value of the Colorado River as a habitat for game fishes by: (1) draining the adjoining backwater lakes and sloughs; (2) eliminating riparian vegetation cover; (3) eliminating the eddies and "holes" along the river littoral zone; (4) increasing water turbidity; (5) increasing bank erosion; and (6) reducing the amount of spawning area.

Since little can be undertaken in this area to rectify the losses to the fishery, it is recommended that the Bureau of Reclamation compensate for damages by improving fishing conditions in other portions of the river when the need arises. It is also recommended that, wherever feasible, dredging operations be modified so that a maximum area of lake and slough habitat remains open to the river.

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AGE COMPOSITION OF THE SOUTHERN CALIFORNIA CATCH OF PACIFIC MACKEREL FOR THE 1951-52 SEASON[1]

By JOHN E. FITCH
Bureau of Marine Fisheries, California Department of Fish and Game

This is the second report on the age composition of the Pacific mackerel (*Pneumatophorus diego*) catch for 1951-52 in which some 31½ million pounds of mackerel were landed. The methods of sampling, age determination and estimation of numbers of fish are the same as those used in the first report (Fitch, 1951) which covered the period 1939-40 through 1950-51.

Table 1 presents the length frequency at each age for the 1951-52 season. Lengths of the fish from which otoliths were taken are given in quarter-centimeters. Of the 911 fish in age groups 0 through IX, only 28 were of age group V and older.

Table 2 presents the calculated number of fish landed for each age group 0 through VI+ together with the percentage each comprises of the total number. Nearly 80 percent of the 32 million fish caught during this season were contributed by but two year classes, 1947 and 1948.

Table 3 gives the number of fish landed by year class at each age group, 0 through V, for the seasons 1939-40 through 1951-52 and Table 4 presents the same information in pounds.

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[1] Submitted for publication September, 1952.

TABLE 1

Length of Fish in Quarter Centimeters at Each Age for the 1951-52 Season, Based on Otoliths Read

¼cm	Age group								
	0	I	II	III	IV	V	VI	VII	VIII
89	1								
90	1								
1									
2									
3	3								
4	2								
95	1								
6	4								
7	3								
8	1								
9	4								
100	2	1							
1	1	1							
2	1	3							
3	2	5	1						
4		3							
105		3							
6		10							
7		4	1						
8		5	1						
9		7	1						
110		4	6						
1		5	2						
2		9	6						
3		8	3						
4		10	6	1					
115		8	5	3					
6		5	8	1					
7		3	12	3					
8		4	6	9					
9		3	10	4					
120			11	10					
1			10	6					
2			5	9					
3			12	13					
4			21	17					
125			12	16	1				
6			4	11	1				
7			4	8	3				
8			8	14	4				
9			9	21	2				
130			1	32	4				
1			4	19	2				
2			1	23	5				
3			1	15	6				
4			2	14	9				
135				15	7				
6				9	19				
7				10	25				
8				2	18				
9				2	16	1			
140					19				

TABLE 1—Continued

Length of Fish in Quarter Centimeters at Each Age for the 1951 52 Season, Based on Otoliths Read

¼cm	Age group								
	0	I	II	III	IV	V	VI	VII	VIII
1				1	35				
2				2	26				
3				3	7	1			
4				1	15	1			
145					8	1			
6					20	1			
7					9	2			
8				1	12	1			
9					3	1			
150					1				
1					2	1	1		
2					2	1	1		
3									
4					1		1		
155						2	1	1	
6									
7									1
8						1			
9								1	
160									1
1									
2							1		
3									
4									
165							1		
6									
7									
8									
169							1		
Sum	26	101	173	298	285	17	7	2	2

TABLE 2

Calculated Number of Fish Landed for Age Groups 0 Through VI+ for the 1951-52 Season
Percentages of Season's Contribution by Numbers and Year Class Are Also Indicated

	Age group							Totals
	0	I	II	III	IV	V	VI+	
Year class	1951	1950	1949	1948	1947	1946	----	
Number of fish	769,000	1,583,000	4,428,000	13,871,000	11,127,000	218,000	154,000	32,150,000
Percent of landings	2.4	4.9	13.8	43.1	34.6	0.7	0.5	100.0

TABLE 3

Number of Fish Landed by Year Class at Each Age Group From 0 Through V, 1939-40 Through 1951-52

Year class	Age group 0	I	II	III	IV	V	Totals
1934						5,340,000	
1935					10,570,000	1,443,000	
1936				35,130,000	13,551,000	970,000	
1937			26,540,000	25,261,000	5,121,000	822,000	
1938		25,200,000	69,322,000	25,661,000	5,271,000	1,082,000	[illegible]*
1939	2,960,000	20,793,000	26,454,000	12,698,000	7,133,000	1,616,000	71,654,000
1940	2,313,000	12,507,000	9,201,000	10,156,000	7,712,000	[illegible]	[illegible]
1941	398,000	29,376,000	54,106,000	33,905,000	10,312,000	[illegible]	[illegible]
1942		12,162,000	19,047,000	10,259,000	[illegible]	[illegible]	[illegible]
1943	836,000	16,556,000	10,327,000	11,872,000	5,087,000	[illegible]	[illegible]
1944		11,302,000	25,823,000	10,943,000	1,105,000	[illegible]	[illegible]
1945	556,000	9,330,000	7,980,000	756,000	[illegible]	[illegible]	[illegible]
1946	560,000	1,377,000	3,175,000	4,279,000	[illegible]	[illegible]	[illegible]
1947	7,181,000	63,330,000	49,255,000	15,826,000	[illegible]		[illegible]
1948	1,061,000	21,818,000	19,228,000	[illegible]			[illegible]
1949	136,000	3,854,000	1,128,000				[illegible]
1950	6,000	1,583,000					
1951	769,000						

* No information available on the 0 age group of the 1938 year class.

TABLE 4

Pounds of Fish Landed by Year Class at Each Age Group 0 Through V, 1939-40 Through 1951-52

Year class	Age group						Totals
	0	I	II	III	IV	V	
1934						6,851,000	
1935					12,141,000	1,885,000	
1936				31,946,000	14,592,000	1,414,000	
1937			19,306,000	22,163,000	7,015 000	1,178,000	
1938		11,578,000	49,762,000	27,249,000	6,651,000	1,499,000	96,739,000*
1939	961,000	11,609,000	21,747,000	12,898,000	9,058,000	2,334,000	58,607,000
1940	853,000	7,564,000	7,809,000	10,743,000	10,139,000	4,809,000	41,917,000
1941	116,000	15,085,000	40,066,000	36,527,000	13,595,000	3,236,000	108,625,000
1942		7,912,000	16,208,000	11,453,000	6,225,000	2,863,000	44,661,000
1943	274,000	9,991,000	9,221,000	12,786,000	6,718,000	638,000	39,628,000
1944		7,296,000	22,530,000	13,035,000	1,484,000	852,000	45,197,000
1945	158,000	5,627,000	7,601,000	867,000	899,000	100,000	15,252,000
1946	129,000	1,015,000	2,365,000	4,070,000	1,078,000	290,000	8,947,000
1947	1,477,000	29,643,000	32,320,000	14,692,000	12,819,000		90,951,000
1948	248,000	8,612,000	13,591,000	13,327,000			35,778,000
1949	47,000	2,155,000	3,547,000				5,749,000
1950	1,000	802,000					
1951	252,000						

* No information available on the 0 age group of the 1938 year class.

NOTES

SLEEPER SHARK, *SOMNIOSUS PACIFICUS*, CAUGHT OFF FORT BRAGG, CALIFORNIA

A male sleeper shark, *Somniosus pacificus*, 13 feet long, was taken by the drag boat MARY LA ROCCA, Captain Frank Davi, in a drag net towed on the bottom, at a depth of 245 fathoms (1,470 feet), west of Fort Bragg, California, May 12, 1952. It was not possible to obtain the weight of this animal, but the tan-colored liver weighed just 200 pounds. The largest individual previously recorded was 11½ feet long, though the species is reputed to reach as much as 25 feet.

The sleeper shark is found in the North Pacific, from Southern California to Japan. Reports of this shark along the California coast are not

FIGURE 1. Sleeper shark, *Somniosus pacificus*, 13 feet long, caught in a drag net in 245 fathoms, west of Fort Bragg, California, May 12, 1952. *Photograph by J. B. Phillips.*

common. The first record in California waters was of a seven-foot specimen taken in a drag net off Pt. Reyes, February 26, 1920 (Scofield, Calif. Fish and Game, 1920, vol. 6, no. 2, p. 80). This shark, a very sluggish animal, feeds on almost any animal life of suitable size and on carrion. It dwells on the bottom of the ocean, but is known to come to the surface at times. The present specimen disgorged several large rockfish, *Sebastolobus alascanus*, a species found in deeper water than are most other rockfishes.

Because detailed descriptions of the Pacific form are meager, the following description and measurements are given.

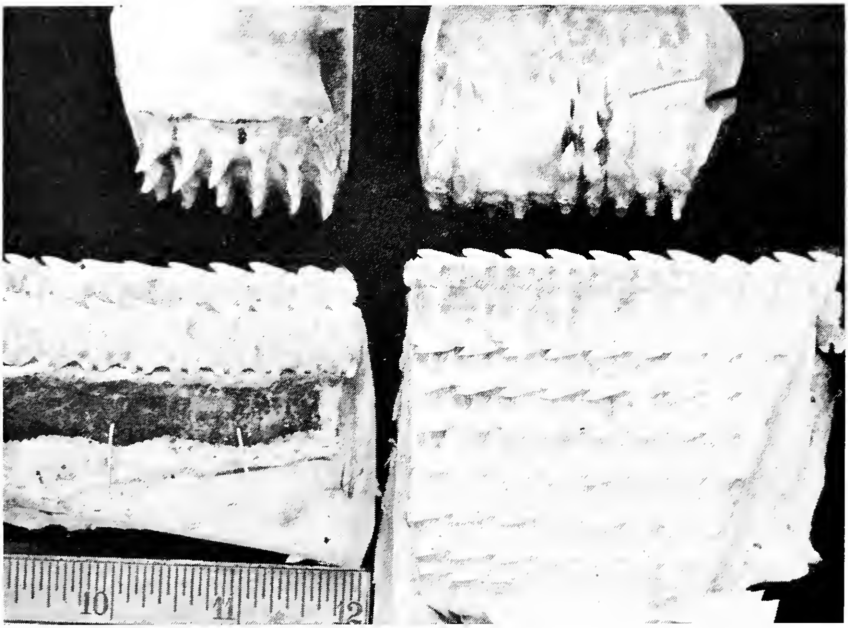

FIGURE 2. Sections of jaws showing teeth of a 13-foot sleeper shark, *Somniosus pacificus*, taken off Fort Bragg, California, May 12, 1952. Left, upper section, outside of upper jaw; left, lower section, outside of lower jaw; right, upper section, inside of upper jaw; right, lower section, inside of lower jaw. Note the several rows of reserve teeth on the inside of jaws; also the reinforcing row of teeth, below the biting edge, in the outside of lower jaw. The numbers on ruler shown represent inches. *Photograph by J. B. Phillips.*

General Description

Color, slate-gray, with darker, streak-like mottling on back. Body elongate, stout and rounded, deep anteriorly. Head large; snout blunt; mouth ventral. Gill slits short, low on side of body; the length of the openings hardly more than 2½ times the diameter of eye. Spiracle opening a short distance behind eye, at least one-half as large as eye. Anal fin absent. Dorsal fins two, about equal in size and shape, rather small and somewhat oblong; no spines. Distance between the dorsals, about equal to greatest body depth. A low median, dermal ridge in front of first dorsal, but absent between the dorsals. Anterior margin of base of second dorsal about over, or slightly posterior to, the posterior margin of base of pelvic fins. Length of pectoral fin 1½ times its base. Upper lobe of caudal moderately larger than lower lobe. Length and height of caudal fin only a little greater than greatest body depth. Middle of base of first dorsal fin approximately one-half the distance between the posterior base of pectoral and the

anterior base of pelvic fins. Labial slit present behind the corners of jaws. Teeth numerous, small, close-set; upper jaw canine-like, thin and sharp-pointed, in lower jaw triangular, with the broad base exposed and canted to one side, somewhat overlapping. The teeth in both jaws with smooth edges.

Measurements in Inches

Total length	155
Greatest body depth (approximate)	26
Depth at caudal peduncle	6
End of snout to eye	11½
End of snout to nostrils, on underside of head	3
Length of each nostril slit	3
End of snout to anterior margin of base of pectoral fin	12
End of snout to anterior margin of base of first dorsal fin	67
Diameter of eye	1½
Rear margin of eye to spiracle	6½
Spiracle opening	1 x [illegible]
Length of gill slits	1
Distance between first and fifth gill slits	12
Width of pectoral fin base	10½
Length of anterior side of pectoral fin	16½
Length of posterior side of pectoral fin	6
Width of pelvic fin base	5½
Length of pelvic fins including claspers	17
Extension of ends of claspers behind pelvic fin, proper	3
Length of base of first dorsal fin	10
Length of base of second dorsal fin	8
Normal height of first and second dorsal fins	3½
Length of anterior side of first dorsal fin, and the posterior sides of the first and second dorsal fins	6½
Length of the anterior side of the second dorsal fin	4
Distance between the first and second dorsal fins	28
Distance from posterior margin of base of second dorsal fin to end of caudal fin	12
Distance from anterior margin of base of pelvic fins, to end of caudal fin	57
Distance from posterior margin of base of pelvic fins to juncture of lower lobe of caudal fin	23
Distance, posteriorly of juncture of lower lobe of caudal fin, to juncture of upper lobe of caudal. (Horizontal measurement)	1
Length of upper lobe of caudal fin	23½
Length of lower lobe of caudal fin	19
Distance from juncture of lower lobe of caudal to the concavity between the upper and lower lobes of caudal fin	17
Distance between eyes	16

—*J. B. Phillips, Bureau of Marine Fisheries, California Department of Fish and Game, June, 1952.*

THE OCCURRENCE OF TWO ADDITIONAL CENTRARCHIDS IN THE LOWER COLORADO RIVER, CALIFORNIA

The capture of the red-ear sunfish, *Lepomis microlophus* (Günther), in the Colorado River establishes this fish as part of the California fresh-water fish fauna and is an addition to the fishes recorded by Shapovalov and Dill (1950) in their "A check list of the fresh-water and anadromous fishes of California."

Red-ear sunfish were seined by the writer from the river four miles below Parker Dam and from a small oxbow lake immediately below Headgate Rock Dam on April 27, 1951. No specimens larger than four inches in length were captured nor has this species yet been observed in the anglers' catch.

The red-ear is distributed throughout the eastern half of the United States and into the southwest as far as Arizona. It probably became established in the Colorado River in 1948 or 1949, since the Arizona Department of Game and Fish made several plants of this species in the Headgate Rock Dam area at that time. It is a desirable pan fish and in Indiana is considered to be superior to the bluegill for stocking in ponds in combination with the larger piscivorous game fishes (Krumholz, 1950).

With the addition of the red-ear sunfish there are now four species of the genus *Lepomis* present in California waters. The following key, taken in part from "Fishes of the Great Lakes Region" (Hubbs and Lagler, 1947), will aid in their identification.

1— Anal spines 3; scales large, 53 or fewer in lateral line; body depth usually about one-half standard length; no teeth on tongue; supramaxilla reduced, its length when present less than greatest width of maxilla (*Lepomis*) 2

2— Upper jaw extending to (or even beyond) middle of eye; pectoral fins short and rounded, contained about four times in standard length.
Green Sunfish, *Lepomis cyanellus* Rafinesque.

Upper jaw not extending nearly to middle of eye; pectoral fins long and pointed, contained a little less to a little more than three times in standard length 3

3— Opercular bone flexible posteriorly; gill rakers long and slender.
Bluegill, *Lepomis macrochirus* Rafinesque.

Opercular bone stiff behind; gill rakers short and stout 4

4— Opercle with definite scarlet spot; cheeks with prominent blue and orange stripes in life; pectoral fins less than one-third standard length in adult; body outlines gibbous.
Pumpkinseed, *Lepomis gibbosus* (Linné).

Opercle with broad scarlet margin; cheeks without conspicuous orange and blue streaks; pectoral fins more than one-third standard length in adult; form more rhomboidal.
Red-ear sunfish, *Lepomis microlophus* (Günther).

Dr. Carl L. Hubbs identified the sunfish new to California.

Not new to California, but new to the lower Colorado, is the smallmouth black bass, *Micropterus dolomieu* Lacépède. In August, 1950, 3,200 fingerling smallmouth bass obtained from the California Department of Fish and Game's Central Valley Hatchery at Elk Grove were stocked in the Colorado River at a point four miles downstream from Parker Dam. To date 12 specimens have been observed in the anglers' catch. One smallmouth taken on December 1, 1951 at a point approximately 10 miles below the planting site measured 11½ inches in fork length. This fish was approximately 18 months old at the time of capture. For growth rate comparison, smallmouth black bass of a similar age from Norris Reservoir, Tennessee averaged 8.9 inches in total length (Stroud, 1948).

Since no record of smallmouth bass spawning in the Colorado River has as yet been obtained, this species cannot yet be considered an established part of the fish fauna. However, the excellent growth and condition of those specimens captured indicates that the smallmouth bass may do well in portions of the Colorado River.

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—*R. D. Beland, Bureau of Fish Conservation, California Department of Fish and Game, September, 1952.*

REVIEWS

Land for Tomorrow

By Dr. L. Dudley Stamp; Indiana University Press, Bloomington, 1952, 230 p. $4.

This book presents a very careful analysis of the world's population and its food needs and presents a method of solving the problem that is the most promising yet proposed.

Dr. Stamp is an English geographer and Professor of Land Use at the London School of Economics. This book is based on a series of lectures given at the University of Indiana in 1950 while the author was a visiting professor. The book goes into considerable detail in defining the problem, particularly population trends. Some rather startling facts are developed which will be of considerable interest to fisheries workers. For example, Dr. Stamp shows that the rate of increase of the middle latitude "white" races actually exceeds the increase of the tropical races. In fact the "white" increase is in the order of four times as rapid as the total population increase.

Dr. Stamp scrutinizes the so-called "Point Four" rather carefully and reaches the conclusion that there are severe technical handicaps that must be solved before its aims can be realized. Instead he proposes that we devote our immediate attention to the lands we know how to manage, namely the middle latitude lands such as the United States where staggering results can be achieved if we can only reach the present production per acre of European lands. With the removal of man-made trade barriers this country alone can go a long ways toward feeding the world.

This book can be highly recommended as an extremely interesting and provocative discussion of our food needs. It seems that Dr. Stamp's conclusions can apply equally well to marine as well as land resources in many cases. One thing that is advocated is a world-wide survey of land use including tropical cultivation. It is hoped that someone will point out in as good a fashion that our marine resources can also be utilized to bring the peace that is not likely in a hungry world.—*R. M. Paul, Department of Fish and Game.*

How to Take Trout on Wet Flies and Nymphs

By Raymond W. Ovington, Jr.; Little, Brown and Co., Boston, 1952; vii + 231 p.; $4. Illustrated by the author.

It is interesting to find, among the new books, one which is specifically devoted to the restricted field of trout fishing with wet flies and nymphs. All too many anglers, disgusted and frustrated in their attempts to teach themselves how to handle a dry fly, switch to the use of wet flies because of a misconception that the latter can be fished successfully with little or no skill. The art of wet fly fishing, however, demands at least an equal amount of ability, and poor dry fly anglers are usually poor wet fly anglers, too. Ray Ovington makes this point handily, but comes to the rescue with facts which should increase their success.

This small volume contains more than the average amount of informative material. Its five chapters cover tackle selection, presentation of wet flies and nymphs, tying wet fly patterns and the striking, playing and landing of trout with these lures. New anglers will especially appreciate the many small tips which are scattered throughout the chapters, and even old timers will welcome the inclusion of methods they have either overlooked or long forgotten. The how-to-do-it instructions are so expertly clear and simple that most readers will be able to go to their pet streams or fly-tying benches and get positive results.

Mr. Ovington is to be commended on the restraint he has exercised. Although he lapses into narration in order to provide some human interest, anecdotes and personal history are kept to a pleasing minimum. Also happily absent are the long and tedious discourses on trout stream entomology and fly patterns which so frequently are more confusing than enlightening. A final omission, somewhat conspicuous by its absence, is a chapter on fish conservation. Most modern angling books make some attempt to include a few remarks regarding this important field. In the present case, however, it is but further proof of how completely Mr. Ovington sticks to his subject.

The angler-reader will find this volume a desirable addition to his collection of angling literature. A modest binding and heavy, fine quality paper with large, clear print make for a clean looking job. In addition, there are some 15 attractive pen-and-ink sketches, 18 photographs and 24 diagrams to illustrate and augment the text.—*Herbert E. Pintler, Department of Fish and Game.*

Between Pacific Tides

By Edward F. Ricketts and Jack Calvin, revised by Joel W. Hedgpeth; Stanford University Press, Stanford, California, 1952; xiii + 502 p., 1 color and 46 black and white plates, 134 figs., $6.

Ever since "Between Pacific Tides" was first published in 1939, it has been almost a necessity for those individuals wishing to know the shallow-water and shore fauna of the Pacific Coast (Baja California to Alaska). A revised edition in 1948 and this, a third edition just four years later, attest its continued popularity.

With the exceptions of those scientific names no longer recognized as appropriate, little of the original text has been changed. In addition to an entirely new chapter entitled "Intertidal Zonation and Related Matters" a two-page section "The Tomales Bay Tidal Flats" has been placed at the end of the chapter on "mud flats" and three paragraphs on fluctuating populations (dinoflagellates, sardines, etc.) have been inserted into the chapter dealing with "plankton."

The annotated references in the appendix have been brought up to date and are of real value to all who wish to further their knowledge of a particular animal or group of animals. Several (but not all) poorly drawn or wrongly identified pen and ink sketches which were used in the two former editions have been reillustrated and their faults corrected, and many new black and white plates have been added. For the most part, the pictures used to make up these new plates represent some of the finest quarium photography it has been my pleasure to view. The remainder of the plates, though showing signs of wear and tear after three printings, are still generally quite good.

There are several errors in the text which should not be perpetuated, but they exist as falsehoods only because recent (since 1939) research has proved them such. In general, the faults are rather minor and do not rate adverse criticism at this time.

"Between Pacific Tides" in its present form is one of the best and most up to date of the available, popular accounts of Pacific Coast "tide pool" life.—*John E. Fitch, California Department of Fish and Game.*

Life of the Shore and Shallow Sea

By Douglas P. Wilson; The McBride Company, New York, 1952 xvii + 213 p., 45 black and white plates, 10 figs., $3.95.

It would be difficult to find in any book a finer set of black and white plates. If one could ignore the frontispiece, it might be said that no praise can be high enough for the beauty, clarity and artistic merits of these photographs of living marine plants and animals. It is certainly too bad the quality of the text could not have matched that of the photographs. If the author had limited his discussion to one-tenth as many animals and then filled the pages with choice and intimate bits of gossip and fact on the lives of these, the book would have had an appeal to readers the world over.

For more than 100 pages the sentences are clipped, terse and full of scientific names. An example from page 18 "Thus, *Psammosolen candidus* (a kind of razor-shell) lives in shell-gravel, while the closely allied *P. chamasolen* inhabits black mud. Again in three closely related worms, *Glycera lapidum, G. gigantca* and *G. convoluta,* the two former are most usually found in shell-gravel and the latter in mud or muddy sand." All this is excellent if one is interested in determining the typical habitats of as many shore dwellers as possible, but hardly what one would have expected after having read this statement on the inside fly of the jacket: "It is a popular book intended to interest the reader who has little or no previous knowledge of the ways of life of the sea. Devoid of technical terms . . ."

In its present form I fear the book has appeal only to those interested in the biology of marine animals of the coast of England (Plymouth area) or to those specializing in marine ecology or seashore life zones. This book is not recommended for any person seeking a volume which would afford several evenings of pleasant and yet informative reading.—*John E. Fitch, California Department of Fish and Game.*

Fish and Fisheries of Australia

By T. C. Roughley; Angus and Robertson, Sydney, Australia, 1951; 313 p., 60 color and 21 black and white plates. $10.

This is a nontechnical book written in a most pleasing style and designed for anyone with an interest in fishes and fishing. It is, of course, of primary appeal to the Australian, but the American reader will find that it contains a vast quantity of information well worth his attention. Though published in Australia, the book is available through dealers in this country.

Actually, this is Mr. Roughley's second book on Australia's fishes and is based on the first, which was published in 1916 and has long been out of print. The text has been fully revised and expanded; a few of the original color plates are omitted and a few new ones have been added. I feel that the revision went a step too far in that systematic descriptions of the species have been omitted. This limits the usefulness of the book, at least so far as the potential technical purchaser is concerned. But this is not a volume designed for him, though it does include much which will interest the fisheries investigator particularly.

Approximately half of the text is devoted to descriptions of the common fishes, both marine and fresh water. These descriptions, with very few exceptions, do not include any aids to identification and, as noted, in this respect the new book suffers in comparison with the old. They do tell of general relationships, distribution, size, habits and habitat, and of sporting and commercial qualities.

The chapters on fisheries and angling range from aboriginal fishing to underwater spear fishing (using a face plate; the aqua-lung had apparently not appeared on the Australian scene when Mr. Roughley wrote). There is a chapter on trout; both the brown and rainbow have been introduced with success. Other fresh water fisheries, pond culture, big game angling, sharks, commercial fishing and canning, all receive their just due. Fish canning is still a young industry in Australia and the pelagic fisheries remain practically unexploited. The inshore and bottom fisheries, to the contrary, are in the author's opinion already overexploited.—*Phil M. Roedel, California Department of Fish and Game.*

REPORTS

FISH CASES

July, August, September, 1952

Offense	Number of arrests	Fines imposed	Jail sentence (days)
Abalone: Overlimit; undersize; no license; transporting out of shell and in condition that size could not be determined; possession out of shell; taking in refuge; taking with aqualung	18	$1,230 00	
Angling: Three lines; no license; closed waters; 2 rods and lines; night fishing; failure to show license; predating license; illegal license; using another's license; operating set lines; angling in fish refuge; using 5 attractor blades; possessing spear within 300 ft. stream; angling too near lower side of dam and fish ladder; causing stream barrier; fishing from dam near fishway; using seine; using 5 hooks; nonresident using resident license; unattended pole; possessing 2 angling licenses	757	10,981 50	2
Bass: Striped: undersize; overlimit; 2 lines; mutilated so size and weight could not be determined. Black: overlimit and seining; closed season	81	2,382 00	15
Catfish: Overlimit; bringing illegally into State; set lines; at night and with 2 poles	9	330 00	
Carp: No license	2	50 00	
Clam: Pismos: Overlimit; undersize; no license; in refuge; closed season; failure to bury undersize; digging in state preserve; possession out of shell. Cockles: overlimit; closed season and undersize. Big necks: overlimit	11	1,065 00	10
Commercial: No license; selling undersize tuna; possessing abalone out of shell prior to delivery; working on commercial abalone boat without permit; selling live fish without license; failure to procure party boat permit; striped bass on commercial boat; taking undersize abalones commercially; selling undersize albacore; unloading yellowtail caught in Mexico without permit; bringing fish ashore to sell without commercial license; failure to register fishing vessel; sale striped bass; overlimit frogs; market owners possessing spiny lobsters in closed season and marking without supervision; fish dealers failing to keep records; failure to make out correct fish receipts; possessing untagged catfish; possession of untagged trout by market; possession of abalone commercially without permit; overlimit and nndersize barracuda and sale of undersize; selling undersize yellowtail; nsing net to take salmon between sunrise Saturday and sunset Sunday	115	9,725 00	
Crab: Taking females	1	25 00	
Frog: Overlimit; closed season	1	225 00	
Lobster: Closed season	2	50 00	
Perch: Overlimit	3	237 00	
Pollution: Mill refuse; oil; discharging saniclor into state waters; sawdust in creek; liquids from log pond in creek	10	1,600 00	
Rockfish: Overlimit	2	35 00	
Salmon: Undersize; overlimit; no license; snagging; 2 poles	17	155 00	
Smelt: Dipping without license	1	10 00	
Sunfish: Overlimit and failure to show license; closed season; no license	16	550 00	
Trout: Closed season; overlimit; closed stream; 2 poles; no license; using more than one outfit; chumming with corn; no license; using borrowed license; closed waters; set lines; 3 poles	97	3,785 00	
Total	1,209	$32,738 50	27½
Sale of seized fish		736 30	
Grand total		$33,474 80	

GAME CASES
July, August, September, 1952

Offense	Number of arrests	Fines imposed	Jail sentences (days)
Beaver: Taking closed district	1	$250 00	----------
Deer: Failure to carry tags; taking spotted fawn; night hunting and taking doe; possession untagged deer and failure to retain hide; failure to fill out tags; taking spike buck; taking closed season; carrying another's tags; shooting within 150 yards of dwelling; shooting from road; failure to tag; hunting in refuge; using A tag in B tag district; hunting closed district; taking 2 does and using spotlight; failure to retain horns and hides; no license; failure to have tags punched and countersigned; taking forked horn in refuge; transferring tag; taking with .22 rifle	227	18,651 50	1,085
Deer meat: Possessing unstamped meat; illegal possession; selling; possession without license, tags or transport permit	34	3,575 00	245
Dove: Closed season; overlimit; no license; taking from auto; early shooting; unplugged gun; shooting within 150 yards of dwelling; shooting from public road	94	3,680 00	8
Duck: Closed season; no license	13	1,195 00	----------
Goose: Closed season; selling	2	50 00	----------
Hunting: Loaded gun in car; trespassing; spotlight in game area; shooting from car; night hunting; shooting from public road; no license; late shooting; shooting within 150 yards of dwelling; discharging gun in refuge	631	14,278 00	13
Nongame birds: Taking blue heron, grouse, kingbird, monkey-faced owl, seagull, avocet	8	260 00	----------
Pheasant: Illegal possession from out of State; shooting in closed season, possessing hen; no license, loaded gun in car; shooting from car; taking without tags	31	2,450 00	----------
Pigeon: Overlimit; taking bandtails, closed season	2	125 00	----------
Quail: Taking in closed season	11	745 00	----------
Rabbit: Taking in closed season, at night; spotlighting; no license; loaded gun in car; shooting from car; hunting with .22 rifles; using unplugged gun	131	4,860 00	12½
Sagehen: Taking protected game bird	1	50 00	----------
Squirrel; gray: Taking in closed season	1	25 00	----------
Sheep: Taking young ram	1	250 00	----------
Totals	1,188	$50,444 00	1,363½

SEIZURES OF FISH AND GAME
July, August, September, 1952

	Number	Pounds
Fish:		
Abalone	464	512
Albacore	----------	455
Barracuda	225	----------
Bass	731	135
Clam	121	----------
Carp	1	----------
Catfish	58	475
Frog	111	20
Lobster	1	920
Perch	312	----------
Rockfish	46	----------
Salmon	32	----------
Sunfish	666	----------
Trout	1,686	90
Yellowfin tuna	----------	437,474
Yellowtail	----------	1,226
Game:		
Beaver	1	----------
Bear	1	----------
Deer	94	----------
Deer meat	----------	682
Dove	501	----------
Duck	151	----------
Goose	6	----------
Nongame birds	9	----------
Pheasant	41	----------
Pigeon	16	----------
Quail	41	----------
Rabbit	226	----------
Sagehen	2	----------
Sheep (Mountain)	1	----------

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Notice is hereby given that the Fish and Game Commission shall meet on January 2, 1953, in the California State Building, Los Angeles, California, to receive recommendations from its own officers and employees, from public agencies, from organizations of private citizens, and from any interested party as to what, if any, orders should be made relating to fish, mollusks, crustaceans, amphibia, reptiles, birds, and mammals or any species or variety thereof.

Notice is hereby given that the Fish and Game Commission shall meet on January 30, 1953, in the State Building, San Francisco, to hear and consider any objections to its determinations and proposed orders in accordance with Section 14.2 of the Fish and Game Code, such determinations and orders resulting from hearing held on January 2, 1953.